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# Le développement de la hiérarchisation logique des catégories

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Le développement de la hiérarchisation logique des catégories

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# RÉSUMÉ

Cette thèse s'intéresse à la hiérarchisation des catégories et à l'acquisition de la notion d'inclusion chez l'enfant d'âge scolaire, aux différentes étapes menant à cette acquisition et aux méthodes d'évaluation permettant d'identifier ces étapes. Le corps de la thèse comprend trois articles.

Le premier article présente une analyse des diverses conceptions théoriques du développement de la notion d'inclusion et des tâches susceptibles d'en évaluer la compréhension chez l'enfant. Certains postulats de la vision traditionnelle du développement de l'inclusion, partagés, entre autres, par l'école piagétienne, sont aujourd'hui ébranlés par plusieurs résultats empiriques et par une nouvelle conception du développement des hiérarchies et de la notion d'inclusion (Blewitt, 1989, 1993) qui semble prometteuse. Cette conception repose sur la fragmentation de la notion d'inclusion en différentes composantes qui, elles, seraient acquises à des moments distincts du développement. Selon Markman (1989), une tâche évaluant la capacité des enfants à procéder à des inférences qualitatives pourrait cerner l'acquisition de ces composantes. Plusieurs tâches d'inférence qualitative font l'objet d'un examen critique dans cet article théorique et c'est à partir des conclusions tirées sur leur utilité respective que nous avons pu choisir l'une d'entre elles pour nos études empiriques.

Les performances des enfants à cette tâche qualitative et à l'épreuve de quantification de l'inclusion (épreuve piagétienne qui consiste en fait en une tâche d'inférences quantitatives) n'ont jamais été comparées empiriquement. Une telle comparaison chez des enfants de 5, 7 et 9 ans constitue l'objectif principal de notre première étude, rapportée dans l'article 2. Nos résultats ont permis d'établir qu'une

composante de la relation d'inclusion, la transitivité, est comprise avant sa composante asymétrique. Il appert que la capacité globale des enfants à faire des inférences qualitatives quelle que soit la notion en jeu dans ces inférences –transitivité ou asymétrie- n'est pas acquise plus tôt que leur capacité à faire des inférences quantitatives et ce, contrairement à ce que Markman (1989) avait suggéré. Cette étude constitue la première vérification empirique des niveaux 2 et 3 du modèle de Blewitt. La séquence développementale observée confirme certains aspects du modèle tout en précisant la nature de ces deux niveaux qui tiendraient davantage du concept sous-jacent à l'inférence (transitivité ou asymétrie) que du type d'inférences (qualitatif ou quantitatif).

Enfin, une deuxième étude empirique visant à vérifier si les inférences de l'enfant, qualitatives et quantitatives, sont influencées par le niveau hiérarchique des catégories en cause est présentée dans notre troisième article. Les résultats obtenus auprès d'un nouvel échantillon d'enfants de 5, 7 et 9 ans montrent que le niveau hiérarchique a un effet sur la capacité à faire des inférences qualitatives adéquates, ce qui rendrait compte d'une précocité de la compréhension de la relation d'inclusion pour certains niveaux hiérarchiques par rapport à d'autres. Ces résultats permettent d'identifier certaines contraintes développementales qui freinent l'acquisition de la notion d'inclusion et l'âge auquel ces contraintes sont le plus susceptibles de modifier la compréhension qu'en a l'enfant.

Mots-clés : Inclusion, hiérarchie, développement, catégories, logique des classes, déduction.

## ABSTRACT

This thesis focuses on the hierarchical organization of categories, the acquisition of inclusion, the different milestones leading to this acquisition in school-aged children and on the assessment methods allowing to identify these developmental steps. The body of the thesis is divided into three articles.

The first one presents a review of the theoretical conceptions of the acquisition of inclusion along with an analysis of the tasks evaluating the child's understanding of this notion. Recent experimental results challenged some assumptions of the Piagetian account of inclusion acquisition and led to a new model of hierarchical knowledge and its development (Blewitt, 1989, 1993). This model is principally based on the partitioning of the notion of inclusion into its different components, which should be acquired at different times across the development. According to Markman (1989), it may be possible to assess the acquisition of those constitutive components by evaluating the children's capacity to produce qualitative inferences. This theoretical review proposes a critical analysis of many qualitative inference tasks. It is the conclusions about their respective utility that motivated the choice of the task used in our subsequent work.

The comparison of children's performance at the qualitative inference task thus chosen and at the traditionally criterial quantification task (a Piagetian task which could be referred to as a quantitative inference task) was the aim of the study presented in the second article. The results of such a comparison in children of 5, 7 and 9 years of age, allowed us to point out that one constitutive component of inclusive relation, the transitive aspect, was understood before its asymmetrical component. In contrast with Markman's (1989) claim, the global capacity to produce qualitative inferences, i.e. the

capacity to produce qualitative inferences whether they are based on transitivity or asymmetry, did not appear to be acquired earlier than the capacity to make quantitative inferences. This study is the first empirical attempt to verify the boundaries between level 2 and 3 in Blewitt's model. While supporting some aspects of the model, the developmental patterns we observed specify the nature of these levels which has more to do with the notion underlying the inference (transitivity or asymmetry) than with the type of inference (qualitative or quantitative).

Finally, a second empirical study, conducted with a new sample of children of the same age and reported here in our third article, investigated the effect of the hierarchical levels of categories on children's quantitative and qualitative inferences about inclusion. The results showed that the hierarchical level has an effect on the children's ability to produce adequate qualitative inferences, suggesting that some inclusive relations are understood before others. These findings help identify the developmental constraints that may affect the acquisition of inclusion and the ages at which these constraints are effective.

Keywords : Inclusion, hierarchy, development, categories, class inclusion reasoning, deduction.

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## Remerciements

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# Chapitre 1

## Introduction

Qu'il soit question des catégories naturelles comme les animaux, les fleurs, les fruits ou d'objets fabriqués tels les véhicules ou les vêtements, les différentes catégories d'un domaine donné sont souvent organisées de façon hiérarchique. Les hiérarchies constituent l'une des formes d'organisation les plus répandues qu'utilisent l'enfant comme l'adulte pour se représenter le monde et plusieurs processus cognitifs, tels la mémorisation et la capacité d'inférer des informations lorsque l'on fait face à la nouveauté, s'appuient sur cette organisation. Malgré son importance et l'intérêt qu'elle a suscité depuis longtemps chez les chercheurs en psychologie du développement, la constitution par l'enfant de hiérarchies s'appuyant sur la notion d'inclusion et les différentes étapes de cette constitution ne font pas consensus.

Le présent chapitre situe d'abord la thèse quant au contexte général de l'étude de la catégorisation. Dans un deuxième temps, les deux approches ayant cours quant au développement des hiérarchies inclusives sont présentées. L'une d'entre elles, stipulant le passage du schématique au taxonomique dans l'organisation que l'enfant tente de faire de ses connaissances, recrute plus d'adeptes. Elle rassemble des chercheurs venant des deux côtés de l'Atlantique (par exemple, Houdé en Europe ou Nelson et ses collègues aux États-Unis) et peut être considérée comme étant de la même lignée que les conceptions traditionelles du développement telle celle de l'école piagétienne. L'autre approche est plus marginale et propose un développement des hiérarchies inclusives qui procède non pas d'un passage du schématique au taxonomique mais « du taxonomique au taxonomique » où des capacités taxonomiques de plus en plus élaborées se succèdent au cours du développement. D'origine américaine, ce modèle a été élaboré à la suite de l'accumulation de résultats empiriques mettant en doute le lien génétique entre l'organisation schématique et l'organisation taxonomique. Notre thèse portera principalement sur ce dernier modèle et sur sa vérification. Abordées ici de façon succincte, ces deux approches feront l'objet d'une présentation plus détaillée au chapitre 2.

Le modèle stipulant une évolution au sein même du registre taxonomique (passage « du taxonomique au taxonomique ») requiert de nouvelles méthodes d'évaluation. La discussion sur l'ensemble des tâches susceptibles de répondre aux défis posés par cette nouvelle approche et l'argumentation sous-tendant le choix de la tâche pour la réalisation de nos travaux expérimentaux seront présentées au chapitre 2. Par ailleurs, les modifications ayant dû être apportées à cette tâche à la lumière des résultats obtenus lors de préexpérimentations seront traitées dans le troisième chapitre.

Enfin, la présentation des objectifs à l'origine de nos deux études empiriques rapportées aux chapitres 3 et 4 complète ce chapitre.

Catégorisation écologique et catégorisation logique

Avant d'aborder les deux modèles de développement des hiérarchies inclusives qui prévalent, il importe de situer nos travaux dans un contexte plus global. En effet, il existe deux modalités de catégorisation. La catégorisation écologique s'appuie sur la rencontre dans l'environnement d'attributs plus ou moins fréquents dans la caractérisation des exemplaires d'une catégorie donnée. Ainsi, avoir des ailes et être capable de voler constituent deux attributs fréquents chez les oiseaux. Ces attributs jouent donc un rôle important dans la définition du concept d'oiseau et rendent certains exemplaires de cette catégorie (comme le moineau) plus typiques, plus représentatifs du concept d'oiseau que d'autres (comme l'autruche ou le manchot) qui possèdent moins d'attributs communs avec les autres membres de la catégorie (Rosch & Mervis, 1975). Ce type de catégorisation, aussi appelée prototypique, a non seulement permis l'identification de différents niveaux de typicité chez les exemplaires d'une même catégorie mais a aussi révélé que certains niveaux hiérarchiques de catégorisation (les oiseaux par rapport aux merles, ou les vaches par rapport aux mammifères ou aux animaux) sont plus accessibles que d'autres (Rosch et al., 1976). À la base de tout un courant de recherche, la catégorisation écologique rend compte de la formation des catégories chez l'être humain et des processus d'identification et d'inférences inductives qui lui permettent de déterminer l'appartenance catégorielle d'exemples spécifiques (Osherson & Smith, 1990). On peut retrouver l'origine de cette conception (le côté probabiliste en moins) chez les empiristes (comme Hull) qui considéraient qu'un concept « chien » était formé grâce à l'abstraction d'attributs invariants que l'individu arrive à concevoir à la suite de ses rencontres répétées avec des chiens.

La catégorisation logique (ou classique) à laquelle souscrivent, entre autres, Jean Piaget (Inhelder & Piaget, 1967) et Lev Vygotsky (1962) s'oppose en partie à cette vision empiriste de la formation des concepts. Bien que la vision empiriste puisse tenir compte de la formation des concepts spontanés, une telle vision ne peut tenir compte des concepts relationnels mathématiques ou scientifiques plus complexes tels l'énergie. Les tenants de la catégorisation logique ont proposé une vision plus rationnaliste de la formation des concepts où ceux-ci résultent d'une activité de réflexion. Les catégories ainsi formées y sont définies par des caractéristiques nécessaires et suffisantes, caractéristiques présentes chez l'ensemble des membres de cette catégorie. Par exemple, le fait d'allaiter ses petits ou d'avoir quatre côtés égaux constituent respectivement les caractères définitoires (à la fois nécessaires et suffisants) de la catégorie des mammifères ou de celle des carrés. Tous les exemplaires (mon chien, Lassie et Fido) et toutes les sous-catégories (les teckels, les dalmatiens) d'une catégorie possèdent les caractéristiques définitoires du concept. Dans ce type de catégorisation, il n'y a pas d'exemplaires plus typiques ou plus représentatifs que d'autres et l'on considère, par exemple, qu'un carré n'est pas plus typique qu'un autre. Pourtant, on sait aujourd'hui que la typicité est un phénomène dont l'influence est manifeste non seulement dans la conception des catégories naturelles mais aussi dans la catégorisation d'exemplaires appartenant à des catégories logiques telles les nombres pairs (le nombre 2 étant le plus typique), les quadrilatères (ici, c'est le carré qui représente le mieux la catégorie) ou les triangles (mieux représentés par le triangle isocèle que par tout autre triangle). Malgré les lacunes qu'elle connaît quant aux processus sous-tendant la formation des catégories, la catégorisation logique prend sa force dans sa considération des liens qui unissent les différentes catégories entre elles. D'ailleurs, contrairement aux travaux sur la catégorisation écologique, les recherches menées dans l'optique de la catégorisation logique se sont davantage intéressées aux relations intercatégorielles qu'au savoir intracatégoriel. Ces recherches, le plus souvent développementales, ont porté sur la notion d'inclusion et donc sur une compréhension logique de la relation hiérarchique entre deux catégories. En effet, la catégorisation logique défend une vision classique et aristotélicienne des catégories qui prend sa source dans la logique des classes. Faisant appel à la cohérence interne que doit avoir tout système hiérarchique comprenant plusieurs classes ou catégories, la logique des classes permet de faire des inférences déductives à propos des catégories d'un même système ou à propos de leur lien. Par exemple, la logique des classes permet d'affirmer qu'avec n'importe quelle paire de classes, dont l'une est emboîtée dans l'autre et où aucune n'est vide, la classe englobante contient plus d'items que n'importe laquelle des deux classes englobées.

Longtemps considérées comme opposées l'une à l'autre, ces deux modalités de catégorisation, logique et écologique, semblent coexister chez l'enfant comme chez l'adulte (Barouillet, 1991; Bideaud & Houdé, 1989; Houdé, 1992; Rosch, 1983). La présente thèse fait intervenir des notions issues de l'approche écologique de la catégorisation. Par exemple, notre deuxième étude empirique s'intéresse à l'effet des niveaux hiérarchiques (niveaux identifiés grâce au paradigme de l'approche écologique) sur les capacités de l'enfant à faire certaines inférences. Toutefois, la majeure partie de notre thèse relève de l'approche de la catégorisation logique, en ce sens qu'elle s'intéresse aux relations qu'entretiennent entre elles les catégories d'un même système hiérarchique et aux inférences déductives pouvant être tirées d'un tel système et ce, dans une perspective développementale.

Le développement des hiérarchies inclusives

*Du schématique au taxonomique*. Une hiérarchie comprend des classes ou des catégories plus ou moins englogantes selon leur niveau d'abstraction. Selon la nomenclature de Rosch (Rosch et al., 1976), on retrouve des catégories de niveau surordonné, par exemple celle des animaux, des catégories du niveau de base comme celle des chats et d'autres de niveau subordonné comme celle des siamois. Chez l'adulte, ces catégories sont liées entre elles par la relation d'inclusion, où chaque classe du système hiérarchique est incluse dans les classes de niveau supérieur et inclut les classes de niveau inférieur. Chez l'enfant par contre, l'existence de telles hiérarchies reposant sur la relation inclusive a longtemps été niée au profit d'une autre organisation des catégories reposant plutôt sur les liens schématiques qu'elles entretiennent que sur leurs liens taxonomiques (Bruner, Olver & Greenfiled, 1966; Inhelder & Piaget, 1967; Smiley & Brown, 1979 ; Vygostky, 1962). Selon ce point de vue, la connaissance qu'a l'enfant des objets est d'abord fondée et organisée en fonction des relations spatiales ou temporelles qu'ils entretiennent (oiseau et nid, chien et os) et ce serait vers 7-8 ans seulement que les objets entretiendraient finalement des liens taxonomiques (animal et chat) ne reposant ni sur la temporalité, ni sur la contingence spatiale ou fonctionnelle. Cette conception du développement, préconisant un changement de l'organisation en mémoire passant du schématique au taxonomique, a été reprise plus tard par d'autres chercheurs (Houdé, 1992; Lucariello, Kyratzis & Nelson, 1992; Lucariello & Rifkin, 1986; Nelson, 1988) pour qui les relations taxonomiques en développement seraient non seulement consécutives aux relations schématiques mais seraient également dérivées de celles-ci. Ainsi, l'enfant organiserait d'abord les objets en fonction du contexte dans lequel ils apparaissent, c'est-à-dire en fonction du scénario ou du script auquel ils appartiennent : par exemple des objets comme un ballon, une serviette et des sandales feraient partie du scénario « aller à la plage » . Cette représentation schématique des objets ferait place à des représentations intermédiaires où s'intallerait une certaine substituabilité entre les objets. Par exemple, le ballon issu du script de la plage ne ferait plus partie d'une représentation comprenant la serviette et les sandales qui ne lui sont liés que thématiquement, mais partagerait maintenant des liens avec des objets qui sont substituables les uns aux autres à l'intérieur d'un même script. La nouvelle représentation ainsi formée du ballon, du frisbee, du seau et de la pelle, par exemple, pourrait constituer la catégorie des « jeux de plage ». Les

« animaux de la ferme » ou les « animaux de la jungle » constituent deux autres exemples de ces représentations où les objets sont contigus et donc encore liés temporellement et/ou fonctionnellement, mais plus susbtituables les uns aux autres que dans la représentation proprement schématique (Houdé, 1992). Pour ces chercheurs comme pour ceux de l'école piagétienne, la forme finale d'organisation des catégories serait de nature taxonomique et décontextualisée et l'âge d'acquisition de cette organisation se situerait autour de 7-8 ans.

Plusieurs résultats empiriques infirment l'existence de ce passage d'un mode schématique à un mode taxonomique d'organisation des connaissances. Comme on le verra de manière plus détaillée au chapitre 2, non seulement les enfants d'âge préscolaire semblent détenir certaines habiletés taxonomiques et préfèrent même, dans certaines conditions, les relations taxonomiques aux relations schématiques (Bauer & Mandler, 1989; Callanan, Repp, McCarthy & Latzke, 1994; Davidson & Gelman, 1990; Dunham & Dunham, 1995; Gelman & Coley, 1990; Gelman & Markman, 1986; Gentner & Namy, 1999; Golinkoff, Shuff-Bailey, Olguin & Ruan, 1995; Graham, Baker & Poulin-Dubois, 1998; Houdé, 1990; Mervis & Crisafi, 1982; Sugarman, 1982; Waxman & Hall, 1993), mais les enfants d'âge scolaire, les adolescents et les adultes privilégient aussi des stratégies s'appuyant sur les relations schématiques dans certaines conditions expérimentales (Barouillet, 1994; Blewitt & Toppino, 1991; Greenfield & Scott, 1986). En fait, les enfants sont très bien capables de lier les objets à la fois en fonction des liens schématiques et des liens taxonomiques qu'ils entretiennent. La tendance à préférer un type de relation dépendrait largement de facteurs contextuels tels les consignes données par l'expérimentateur, le type d'objet à apparier -bidimensionnel (image) ou tridimensionnel (objet)- (Waxman & Namy, 1997) ou le type de tâches (Blaye, Bernard-Peyron & Bonthoux, 2000) et n'aurait rien à voir avec une tendance de base déterminée uniquement par l'âge du sujet.

*Du taxonomique au taxonomique.* Les données issues de certains de ces travaux empiriques ont amené Blewitt (1989, 1993) à proposer un nouveau modèle de développement des relations taxonomiques. Puisque les relations schématiques ne subissent pas de changement important au cours du développement et qu'il n'est plus possible d'établir une hiérarchie développementale stricte entre relations schématiques et relations taxonomiques, des changements importants doivent nécessairement survenir dans le système taxonomique en soi. Le modèle proposé rend compte de l'acquisition d'une organisation hiérarchique des connaissances et du développement de la compréhension qu'a l'enfant des relations hiérarchiques entre les différents niveaux. Il stipule un continuum où différents niveaux de connaissances prennent place à des moments différents du développement, les niveaux les plus avancés émergeant des niveaux antérieurs, et où chaque niveau de connaissance s'exprime par des habiletés particulières. Le modèle théorique comporte trois niveaux. Au premier niveau, l'enfant serait en mesure de former des catégories de différents niveaux hiérarchiques et pourrait inclure un même objet (Fido) dans plusieurs de ces catégories (chien et animal). Ce niveau caractérise les enfants de 2-3 ans et a été confirmé empiriquement par Blewitt en 1994. Au deuxième niveau, l'enfant serait en mesure de faire des inférences qualitatives face à la nouveauté et d'appuyer ces inférences sur ses connaisances hiérarchiques. Par exemple, lorsqu'on lui dit qu'un « dax » est un chien, il est capable de déduire qu'un dax est un animal. L'enfant de ce niveau sait que, dans leurs liens verticaux, les catégories d'une hiérarchie sont en quelque sorte liées entre elles. Il n'est pas certain toutefois, que l'enfant comprenne que cette relation en est une d'inclusion. Il peut déduire qu'un dax est un animal comme il déduirait qu'un dax est une « chose poilue ». Cette habileté à faire des inférences qualitatives serait dépassée au niveau 3 par la capacité à procéder à des inférences quantitatives à propos de la taille relative de catégories d'une même hiérarchie, inférences comme celles requises dans la tâche de quantification de l'inclusion de Inhelder et Piaget. À ce jour, les niveaux 2 et 3 n'ont pas été vérifiés empiriquement.

Le modèle proposé par Blewitt offre une description de la compréhension que peuvent avoir les enfants d'une hiérarchie inclusive alors qu'ils ne réussissent pas encore la tâche de quantification. Ce modèle s'harmonise avec les derniers travaux de Piaget et Garcia (1987) dont nous reparlerons dans la conclusion et qui portent sur la logique précédant la réussite à l'épreuve de quantification, longtemps considérée comme l'épreuve critère de la compréhension de la notion d'inclusion.

<u>Objectifs</u>

Le but de notre recherche est de vérifier, dans un premier temps, l'existence et la nature des niveaux 2 et 3 du modèle théorique de Blewitt. La capacité qu'ont les enfants à faire des inférences qualitatives et quantitatives y sera donc comparée pour la première fois et ce, dans le but de décrire les étapes menant à la compréhension d'une hiérarchie inclusive, du moins en ce qui a trait aux étapes précédant la réussite à la quantification de l'inclusion. Certaines inférences qualitatives porteront sur la compréhension de la transitivité tandis que d'autres exigeront aussi de saisir le caractère asymétrique des relations d'inclusion.

Dans un deuxième temps, il s'agira de vérifier si la compréhension des notions de transitivité et d'asymétrie est influencée par le niveau hiérarchique des catégories utilisées dans les inférences et ce, dans le but d'étayer davantage les niveaux 2 et 3 du modèle de Blewitt et de mieux saisir les différents éléments qui interviennent dans le développement des hiérarchies inclusives chez l'enfant.

Mais d'abord, le chapitre théorique qui suit traite principalement des deux approches du développement des hiérarchies inclusives, des critiques émises à l'égard de la tâche de quantification de l'inclusion et des autres tâches pouvant rendre compte d'un niveau plus précoce de compréhension de l'inclusion.

**Chapitre 2**

**Article 1**

# The development of inclusion relations:

# Theoretical and methodological considerations.

Joane Deneault

(soumis)

# The development of inclusion:

# Theoretical and methodological considerations.

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## Abstract

Even though many studies were devoted to the understanding of inclusion, the mastery of this notion and the way it develops in children is still an unresolved issue. The aim of this review is to present 1) the classical account of the development of inclusion, 2) a new conceptualization of this development proposed by Blewitt (1989) 3) critics of the class-inclusion task traditionally used to assess the understanding of inclusion, and 4) the methodological options now available to assess inclusion in light of the double challenge posed by Blewitt's model and by some recent findings.



## Résumé

Bien que les études qui ont porté sur la compréhension de l'inclusion aient été nombreuses, la maîtrise de cette notion et la façon dont elle se développe chez l'enfant ne font pas consensus. Le but de cet article théorique est de présenter 1) l'approche classique du développement de l'inclusion, 2) la nouvelle conceptualisation de ce développement proposée par Blewitt (1989), 3) les critiques émises à l'égard de la tâche de quantification de l'inclusion, tâche traditionnellement utilisée pour évaluer la compréhension de l'inclusion et 4) les alternatives méthodologiques qui permettraient de cerner cette acquisition tout en tenant compte des défis posés par le modèle de Blewitt et par les résultats empiriques actuels.

Zusammenfassung

Obwohl viele Studien dem Verständnis der Inklusion gewidmet wurden, stimmen Begriff und Praxis, respektive ihr Entwicklungsverlauf bei Kindern nach wie vor nicht mit der herrschenden Anwendung dieses Begriffs überein. Das Ziel dieses Artikels ist, 1) den klassischen Ansatz der Entwicklung der Inklusion zu skizzieren sowie 2) eine neue durch Blewitt (1989) erarbeitete Konzeptualisierung dieser Entwicklung vorzustellen 3) die Kritiken hinsichtlich der Aufgabe, Inklusion zu quantifizieren, zu erläutern - ein Weg, der üblicherweise eingeschlagen wird, um das Verständnis von Inklusion einzuschätzen, 4) die methodologischen Optionen zu beschreiben, die es derzeit gibt, um die Inklusion im Licht der doppelten Herausforderung seit Blewitts Modell und neuerer Forschungsergebnisse zu bewerten.

Class-inclusion hierarchies are a prevalent form of taxonomic organization. Whether one thinks of objects belonging to natural kind categories like animals, flowers, fruits, or to artifacts like furniture, clothing, or food, relations between things of the outer world are based on this sort of hierarchy. Class-inclusion hierarchies are not only frequent but also essential in many human activities, from defining and remembering objects to making inferences about novelty. For the child who is trying to understand the world, the capacity to organize in a hierarchical manner is indispensable. We know today that children have several abilities relevant to taxonomic knowledge. However, in spite of a large body of research on taxonomic knowledge, often coming from different paradigms in the field of psychology, the extent to which children understand the inclusion relation between categories and represent them in a hierarchically organized system is still a controversial matter (Callanan, 1989; Campbell, 1991; Markman, 1989; Waxman, 1991).

## The Development of Class-Inclusion Hierarchies

A class-inclusion hierarchy is made of multiple classes (or categories) of different levels (dogs, mammals, animals), which are linked by an inclusion relation. Each class of the system is included in classes of superior level and contains the classes below (Piaget, 1971). Most of the literature on the development of this taxonomically organized knowledge in children is concerned with the moment at which this knowledge reaches an adult level and with the existence of an alternative form of organization in young children. Researchers traditionally considered that young children use thematic strategies first and then shift to taxonomic schemes later in the school years (Bruner, Olver, & Greenfield, 1966; Inhelder & Piaget, 1967; Smiley & Brown, 1979; Vygotsky, 1962). In this view, knowledge of objects, for example, is first organized in terms of the temporal or spatial relations they share (e.g. bird and nest, dog and bone). These objects then begin to relate to one another in a taxonomical manner where the relations that unite them become atemporal, non spatial and hierarchical in format (Mandler, 1983) like the relation between dog and animal. Today, some researchers (Houdé, 1992; Lucariello, Kyratzis & Nelson, 1992; Lucariello & Rifkin, 1986; Nelson, 1988) hold a similar point of view according to which the development of taxonomic relations is derived from scripts which are generalized representations of recurring events, such as "getting dressed" or "going to the zoo". After thematically organizing objets in the context within which they appear (e.g. putting bathing suit, towel, and beachball in the same thematic category), children begin to abstract "slot-fillers categories" which are constituted of objects that can replace one another in a particular script (e.g. lion, elephant and giraffe in the "go to the zoo" script, or shirt, skirt, dress, slacks in the "getting dressed" script). A slot-filler category is said to be taxonomic because the different objects that form it are not necessarily contiguous in space or in time. Gradually, since several "slot-filler categories" (farm animals, zoo animals) will be referred to by the same label (animals), children of about 7 years of age will form "real" taxonomic categories that are completely decontextualized (Nelson, 1988)[1]. Whether script-based relations are only taxonomic relations coupled with the effect of traditional mechanisms like associativity and typicality, remains an open question (Krackow & Gordon, 1998). However, although Nelson's explanation for the formation of taxonomic categories is different from Piaget's in terms of the mechanism believed to be responsible for the child's acquisition of hierarchical taxonomic organization (the formation of slot-filler categories vs logical reversibility of operations), they both support the view that children have a hierarchical organization of knowledge at about 7-8 years of age and that this organization is the result of a shift from thematic (or schematic or script-based) to taxonomic organization.

The Piagetian method used to evaluate the child's hierarchical knowledge provided evidence for this shift. In the Piagetian perspective, two related tasks were meant to assess the understanding of taxonomic relations that take place between categories: the object classification task and the class inclusion task (Inhelder & Piaget, 1967). In the classification task, where geometrical figures must be grouped together, young children try to classify geometrical figures in function of their similarity, but change the criterion of their grouping (by color and then by form) while performing the classification. In such a case, it is the similarity between two adjacent objects that determines the collection the child makes. The final collection takes the form of a discontinuous and partial alignment of objects or of a scene as suggested by the name of this stage : "collections figurales". At the end of the preschool years, children enter the stage of "collections non figurales", where they classify all the figures according to one criterion only, proceeding by successive adjustments. Finally, at about 7-8 years, children reach an adult level of classification, the logical classification stage: they become able to hierarchically classify the figures, they show retroactive mobility and anticipation in combining and dividing classes, and their classifications contain more subdivisions. However, for Inhelder and Piaget, evidence of the child's real understanding of the inclusion relation that underlies this classification behavior comes from her capacity to successfully pass the criterial task of class inclusion. This task requires judgments on the relative size of a set of objets that are vertically connected in the same hierarchy. For example, the child might be presented with five roses and three daisies and asked whether there are more roses (subset) or flowers (inclusive set). In the Piagetian perspective, a correct answer to this quantification question requires the reversibility of operations, for the child must be able to simultaneously conserve the superset while maintaining the identity of the subset[2] (Piaget, 1977).

This developmental pattern where the child's organization of knowledge undergoes a shift from thematic to taxonomic categorization has been criticized on two grounds: while some authors questioned the very existence of this developmental shift, others judged that the method employed by Piagetian researchers to assess the taxonomic organization was inappropriate and that the use of an adequate task should demonstrate that children under 7 years of age do resort to a hierarchical organization of categories.

## Is There a Thematic to Taxonomic Shift?

Cumulative results plead against a general and straightforward development from a thematic organization in the preschool years to a later taxonomic organization. First, preschool children appear to have some taxonomic abilities. They are able to form categories of different levels of generality (Callanan, Repp, McCarthy, & Latzke, 1994; Mervis & Crisafi, 1982), to spatially classify similar objects together (Sugarman, 1982) and, in certain circumstances, to choose an object of the same category over a very similar object to match a target (Gentner & Namy, 1999). In a series of studies aimed to identify the role of language in children's inductive inferences, Gelman and her colleagues showed that property inferences made by preschoolers are based on category membership rather than perceptual similarity (Davidson & Gelman, 1990; Gelman & Coley, 1990; Gelman & Markman, 1986)[3].

Second, the existence of a developmental change from thematic to taxonomic organization in children's lexical memory has been challenged or, at least, does not seem as robust as it first appeared. Some results suggested that children between 15 and 21 months do not show a clear preference for thematic relations (Waxman & Hall, 1993). Moreover, it was demonstrated that in some circumstances children have a bias toward taxonomic relations. When asked to choose an object similar to a no-name target, toddlers and preschoolers tended to choose a thematic associate more often than (Golinkoff, Shuff-Bailey, Olguin & Ruan, 1995) or as often as (Graham, Baker, & Poulin-Dubois, 1998; Markman & Hutchinson, 1984) taxonomic associates. But when the target was named by an unknown word, children avoided thematic choices and tended to prefer taxonomic associates (Golinkoff et al., 1995; Graham et al., 1998; Markman & Hutchinson, 1984). With a similar procedure using a no-name target, Dunham and Dunham (1995) again found that 3-year-olds preferred a taxonomic strategy. Bauer and Mandler (1989) also observed a taxonomic preference in children as young as 1 to 2 years of age, in both the "no label" and "novel label" conditions. Studies using classification tasks to demonstrate the role of language in promoting taxonomic relations over thematic ones showed similar results (Waxman, 1990; Waxman & Gelman, 1986) with children between 2 and 3 years (Waxman & Kosowski, 1990). Thus, when tested in conditions using specific linguistic inputs, preschoolers and toddlers can prefer taxonomic relations over thematic ones, thereby challenging the view of a straightforward shift from a thematic to a taxonomic bias in children.

Aubert, Mounoud, and Lewis (1994) found that the preference for thematic or taxonomic strategies can also depend on the nature of the objects involved in a classification task and that the preference for one mode over the other follows a non-monotonic developmental trend, with 6-year-olds using the thematic mode more often than both 4- and 9-year-olds. Studies on adult preference also challenged the thematic-to-taxonomic shift by showing that the privileged status of thematic relations as a knowledge organizer in young children does not seem to change over time. In a study by Blewitt and Toppino (1991), thematic cues were more effective in facilitating recall than taxonomic ones for both preschoolers and college students. Thus, organizing knowledge thematically seems to be a good way of organizing the world even for adults. Moreover, research on conceptual preference revealed that, when using stimuli familiar to the youngest group, schematic relations are preferred from 3 to 15 years of age (Greenfield & Scott, 1986). These results showed that the tendency to thematically organize knowledge does not disappear with age. Thematic and taxonomic modes of organization appear to be both available at an early age (Barouillet, 1994) as well as later, and the children's tendency to focus on one type of relations depends on several situational factors, including the instructions given by the experimenter (Waxman & Namy, 1997) and the task used (Blaye, Bernard-Peyron, & Bonthoux, 2000), rather than on any basic preference determined by age.

Most of the tasks used in the studies on taxonomic abilities (classification tasks, inductive inference tasks, memory tasks, forced-choice object-triad tasks) assessed the kinds of concepts children have formed and the nature of what could count as a member of a given taxonomic category. These studies investigated intracategorical knowledge, but were not concerned with relations between categories, i.e. with intercategorical knowledge. However, their conclusions led some researchers to propose a developmental model of taxonomic knowledge: since no change appears to take place in the thematic conceptual system, and since the thematic-to-taxonomic shift seems weak, Blewitt (1993) suggested that important developmental changes have to occur in the taxonomic system per se. She proposed a model where the understanding of taxonomic knowledge is a continuum within which different forms or levels of hierarchical knowledge take place at different moments in the course of development, the more advanced levels emerging from and depending on the earlier levels (Blewitt, 1989). In the first version of her model (Blewitt, 1989) which was presented as a working hypothesis on the formation of categorical hierarchies, four levels of knowledge and skills were proposed. At level 1, which was presumably acquired at least by age 2, the child should be able to form categories at different levels of generality. Level 2 concerned the ability to include the same object (e.g. Fido) into multiple categories at different levels of generality (in the dog category as well as in the animal category). Necessary to understand and form hierarchies, these abilities were considered at first as two distinct levels, but under empirical scrutiny, they turned out to be available at the same age, between 2 and 3 years (Blewitt, 1994), and therefore constitutive of the first level of a model which henceforth counted only three levels. The second level characterized children who could make qualitative inferences (inductive and deductive) about novel objects. For example, when told that a dax is a dog, they can infer that a dax is an animal. At this level, children know that categories are connected in some way and they can make inferences based on this knowledge. However, they may not yet understand that the relation between these categories is one of inclusion. When inferring that a dax (which is said to be a dog) is an animal, are they doing it the same way they would infer that a dax is a shaggy thing, i.e.

without understanding that the relation between "dog" and "animal" is one of inclusion? Are they making the inference on empirical grounds (the dogs I know are animals, so daxes are probably animals) without understanding the necessity of this inference? Moreover, the extent to which the level 2-child understands the asymmetrical nature of the inclusion relation is not known (if "X" is said to be an animal, is it a cat?). Most of these issues raised by Blewitt relate to the boundaries between level 2 and level 3 which have not yet been experimentally determined. At this third and last level of Blewitt's theoretical model, children should be able to make quantitative inferences about the relative size of a category within a categorical hierarchy. They would perform well on the class inclusion task of Inhelder and Piaget. In a first attempt to distinguish between Blewitt's level 2 and level 3, Bruderlein (1993) compared children on an inference task and on the class inclusion task; however, the insertion of quantifiers in the inference problems prevented him from assessing any precocious ability to make qualitative judgments on inclusive relations.

## Methodological Criticism of the Standard Class-Inclusion Task

Criticized for its account of the development of the child's organization of knowledge through a thematic to taxonomic shift, the traditional view also encountered opposition for the method it used: the quantification problem. On the one hand, the task was said to be too easy: 7-8-year-old children succeed at the task even though they are not able to understand the logical necessity underneath the inclusion relation until 10-11 years (Barrouillet, 1989, 1992; Bideaud & Lautrey, 1983; Campbell & Jantzen, 1994; Cormier & Dagenais, 1983; Markman, 1978; Voelin, 1976). On the other hand, the task was considered too difficult. Some neo-Piagetian researchers (Halford, 1988; Pascual-

Leone, 1988; see Houdé 1992, for a direct application of Pascual-Leone's theoretical frame to the analysis of the class-inclusion task) alleged that the quantification task puts the child in a misleading situation where he has to inhibit an attractive scheme to succeed. For her part, Markman (1989; Markman & Callanan, 1984) claimed that the task requires logical competencies (reversibility) that are not necessary for the comprehension of class-inclusion hierarchies. There have been many experimental attempts to make the task easier by adding perceptual variables, by providing verbal cues to clarify the problem, or by removing distracting cues (see Bideaud, 1988; Winer, 1980, for reviews). However, additional research with these methodological adjustments yielded mixed results: In some studies, the enhancement of children's class inclusion performance was exactly at chance level (leaving no means to distinguish it from mere guessing), in others the enhancement of performance happened to be an artifact, and finally similar methodologies gave opposite results (Cormier & Laurendeau-Bendavid, 1982; Winer, 1980). Performance on class inclusion questions was indeed improved by changing the wording of the question (Which is more, <u>all</u> the fruits or <u>only</u> the lemons?) to conform to standard English usage in a study by Shipley (1979). Five children (out of 21) succeeded at this question while failing the standard one. However, the wording of the question allowed the child to correctly answer it simply by attending to the markers "all" and "only" which indicated the correct answer. This interpretation was not ruled out by Shipley at that time nor by Campbell (1991) who used it later, making it impossible to know if this new version was really easier than the standard one. Shipley did try to solve the problem in her second experiment, where the markers "all" and "only" were opposed to the class relations ("all the lemons", "only the fruits"). But this reverse version of the question was always presented after the correct form, and appreciable order effects were found when similar Piagetian tasks were given to the same subjects in many studies (Gold, 1987). Specifically designed to reject the markers association interpretation, Shipley's third experiment was not convincing either. Only eight children served as subjects, and the markers were assigned to two subsets (lemons and oranges) instead of classes of different levels. Therefore, without further verification, Shipley's version of the task should not be used. In another attempt to facilitate the class inclusion performance, two factors appeared to be of some utility: an explicit request for a subclass comparison (e.g. "Are there more horses or more cows?") before the standard question was asked ("Are there more horses or more animals?")[4], and a procedure requiring the child to sort the materials into a superordinate class (Carpendale, McBride, & Chapman, 1996). However, the effect of these factors seemed moderate. The use of a subclass comparison question before the class inclusion question did facilitate the performance in some conditions. But the effect of the sorting procedure had to be qualified by an interaction with two other variables. Moreover, if the children's justifications were also taken into account, the effect of the sorting procedure was no longer significant. Thus, this procedure should not be adopted if one wants to analyze children's justifications. As demonstrated by Chapman and McBride (1992), there is a good fit between justifications and class inclusion strategies, and the study of verbal justifications in standard class inclusion task should not be abandoned.

In short, it seems difficult to make the class inclusion task easier. And even if one could elaborate a simpler version, in which younger children would perform better than in the standard task, it would not describe nor explain the nature and the development of the understanding of the inclusion relation. For example, if 5-year-olds were made to succeed at a simpler version of the inclusion task, the developmental steps leading to this acquisition would not be better explained than in the old version of the task. A simpler version might in fact explain why success on the standard class inclusion task has not been found at an earlier age, but it could not explain "how that competence developed originally" (Carpendale et al., 1996; Winer, 1980). Maybe this is why some researchers began to search for alternative methods to assess the understanding of inclusion relation.

## Alternative Methodological Options

Inductive reasoning tasks. Many tasks provide a double advantage: they are qualitative and they allow to assess some knowledge of inclusive relations. Johnson, Scott, and Mervis (1997) used an induction task to evaluate the children's understanding of inclusion in one of their experiments. In this kind of task, children are first presented a premise stating that a given known category (e.g. butterfly) has an unfamiliar property (This butterfly has coxa inside its legs) and are then asked to generalize this property to another category, at the same or at a different level (monarch) of the same hierarchy. Admittedly, the patterns of induction that can be derived from a child's answers to such property inference questions are not irrelevant for studying her knowledge about a particular domain and, in the past, their use showed that they are indicative of the child's representation of relations among categories of a given domain (see Carey, 1985 for the biological domain). However, inductive reasoning provides only an indirect account of inclusion relations knowledge. Inductive inferences do not seem to be principally based on category inclusion and the argument that categories inherit the properties of their superordinates does not even explain the adult induction patterns of properties (Sloman, 1998). Rather, these patterns are constrained by the similarity between the premise and the conclusion categories (Lopez, Gelman, Gutheil, & Smith, 1992; Osherson, Smith, Wilkie, Lopez, & Shafir, 1990)[5]. According to Sloman (1996), there are two systems of reasoning: an associative system that is responsible for those patterns just described, and another rule-based system that uses class inclusion reasoning. The use of inductive inference questions in the assessment of inclusion rests on the argument that someone who understands the inclusive relations among categories of a hierarchy will assume that a property of a basic level category, even if not necessarily shared by all of its constituent categories, is more transferable to other categories in this hierarchy than the property of a subordinate level category. In their study, Johnson et al. expected that, when a new property was taught in reference to a basic level category, subjects would be tempted to generate more basic extensions (infer the property to three subordinate categories) than subordinate extensions (e.g. either restrict the property to the category it belongs to in the premise or infer it only to a perceptually similar category), but only adults did exhibit this pattern. These two strategies, i.e. resorting to mutual exclusivity or to perceptual similarity, are primitive. Nevertheless, both adults and children in Johnson et al.'s study used them and did so quite as much: for example, 3-, 5- and 7-year-olds, as well as adults made inferences only to a perceptually similar item in 30%, 41%, 70% and 39% of the cases respectively (Johnson et al., 1997). Although not very indicative of any developmental trend, the inductive property inference task revealed that children do have some knowledge of hierarchical relations: When the new property was introduced in reference to a subordinate level category, children of all ages were more inclined to make restricted subordinate inferences than basic inferences. As the authors put it, "patterns of induction may be used as a window on children's developing appreciation of asymmetry of inclusion" (p. 751). Unfortunately, they do not provide the direct assessment method we are looking for. Qualitative inferences, which require deductive rather than inductive reasoning, may offer a better methodological alternative to assess inclusion.

Deductive reasoning tasks. Although it does not assess the inclusion relation per se, the forced-choice picture task (Bauer & Mandler, 1989; Houdé, 1990; Markman, 1989; Markman & Hutchinson, 1984; Nelson, 1988; Waxman & Gelman, 1986), where children are asked which object goes best with a target one, can reveal that a form of taxonomic organization is available to the child who, for example, will prefer a taxonomic item over a thematic or perceptual one. Being essentially inductive, the task was modified by Houdé and Charron (1995) in order to capture the deductive reasoning about transitivity. This new procedure, adapted from Bryant and Trabasso's (1971) transitivity task, is based on a complex training. The experimenter first makes the child memorize the premises. As in the forced-choice picture task, the child has to choose two items (out of three) that match well. The experimenter then sticks coloured tokens (say pink tokens) behind each of the two chosen items (a lion on one card, an elephant and a crocodile on the other card) as a sign of their relatedness. The child is asked why they are related, as many times as necessary for her to assimilate the relationship. Then the card with the elephant and the crocodile (turned back on the image side) is presented with two new images (one representing a suitcase and a teapot of the same colour as the elephant and crocodile, the other a zebra and a hen) to the child who, again, has to match two items together and justify that match. The experimenter then sticks blue tokens behind the two chosen items (elephant/crocodile and zebra/hen) and again the child has to repeat the reason why they are related in order to memorize it. Since the "elephant/crocodile" card already has a pink token on its back, it ends up with two tokens, a blue one and a pink one. With all the items turned on the token side, the experimenter takes the card with the pink token from the first situation, the card with the blue token and the card with the pink and blue tokens, and then induces the child to produce a transitive reasoning like the following: The card with a pink token goes with the card with two tokens, a pink one and a blue one. This card with two tokens goes with the card with a blue token. So the card with a pink token goes with the card with a blue token. Then, the experimenter leads the child to generalize this reasoning to the animal material. Not only is the procedure used in this task a "heavy" one, but the task itself is more a measure of the child's capacity to make transitive judgments than of her understanding of inclusion : On the one hand, it requires the child to make a transitive judgment between three terms which happen to be categories but could be anything else, and on the other hand, the relation between the categories are associative (goes with…) rather than inclusive (is a…).

There are many deductive tasks that specifically assess inclusion. Quantified questions on familiar categories using quantifiers like "all" or "some" (<u>Are some birds robins? Are all people girls? Are all dogs animals?</u>) are some of them, but they appear to be vulnerable to order effects and to the children's tendency (already identified by Inhelder & Piaget, 1967) to interpret the last question as "<u>Are all dogs all animals?</u>" instead of "<u>Are all dogs some animals?</u>" (Smith, 1979).

Other deductive inference tasks involve unknown elements in the problems they present. It can be an unknown category or an unknown property that the child, who is supposed to infer something in this kind of problem, has to relate to his knowledge.

Although these inference tasks vary a lot in terms of what is unknown in the problems presented, they can be grouped into two categories: property inference tasks and class inference tasks. A property inference task has to use the quantifier “all” not to become an inductive task (All people have spleens in them. Do all children have spleens in them?). Though interesting, this kind of task may be particularly inadequate with natural categories. The properties assigned to natural categories are inevitably internal properties (All animals have ribosomes in them. Do all apes have… All flowers have stamens in them. Do all roses have…: examples adapted from Smith, 1979). And internal properties, contrary to functional ones, were responded to ambiguously by 7-year-olds and by adults (Johnson & al., 1997). Whatever the categories, class inference tasks do not present this difficulty.

Smith (1979) used such a class inferences task. In her study, children where said that a A pug is a kind of dog, and then asked Does a pug have to be an animal? The questions were asked in the two directions of the hierarchy (A pug is a kind of animal. Does a pug have to be a cat?), thus providing a good way to assess the children’s understanding of the two principles on which inclusive relations stand: transitivity and asymmetry[6]. According to Markman (1989), the grasp of both these notions should precede the mastery of the quantification task. Contrary to the Piagetian class inclusion task, the class inference task assesses inclusion understanding without any resort to quantitative reasoning and thus seems a good methodological option to assess Blewitt’s level 2 of hierarchical knowledge.

Although frequently quoted (Blewitt, 1989, 1994; Campbell, 1991, 1992; Campbell & Jantzen, 1994; Markman, 1989) as an empirical support for early understanding of inclusion in 4-year-old children, Smith's study suffers from considerable omissions in the analyses, yielding somewhat unreliable conclusions. The most striking omission is that the performance on the class inference task was globally analyzed without distinguishing between the performance at transitivity questions (upward class inferences) and at asymmetry questions (downward class inferences). The analysis did not provide any information about the relative difficulty of these two notions and complementary analyses of the children's justification patterns did not give any more information since they were made only for transitivity questions.

In the only replication of Smith's experiment, Johnson et al. (1997) found that 3-year-olds showed but a rudimentary knowledge of the asymmetry of inclusion in an inductive task, and that 5- and 7-year-olds still had many difficulties in class and property inference tasks. They concluded that knowledge of inclusion remains fragmentary until after 7 years of age and that a general qualitative shift in children's understanding of inclusion relations is likely to occur after this age. Although adapted from Smith's task, Johnson et al.'s class inference task was somewhat different. Among the modifications they brought, the questions asked to the child in their third experiment did not contain the modal form "have to". In Smith's study, the use of such modal questions had produced somewhat odd patterns of errors. Seventy percent of the non-adult responses conformed to one of the two following patterns: 1) consistently making errors on indeterminate items, either by saying "yes" to all the indeterminate items or by saying sometimes "yes" and sometimes "no" without giving any importance to the phrase "have to" in the question; 2) failing the determinate items by systematically answering "no" to these questions or by switching from "yes" to "no". As Smith said, children who answered according to this latter pattern were probably influenced by the "have to" phrase and may have felt that, in this type of situation, "nothing has to be". Until then, many findings had demonstrated that children's understanding of modal expressions seemed to be precarious. Three-, 4-, and 5-year-olds gave similar responses to "has to" and "might" questions relative to indeterminate situations, suggesting that they did not appreciate the distinction (Byrnes & Duff, 1989). Even with 8- and 9-year-olds, the use of modal expressions such as "has to" did not reduce the difficulty to recognize indeterminacy (Falmagne et al., 1989). For these reasons, Johnson et al.(1997) were justified to abandon the use of modal terms in qualitative inference questions in their experiment. The reintegration of the modal form "have to" in their fourth experiment, however, remains to be explained.

Conclusions on children's understanding of inclusion are difficult to draw from Johnson et al.'s study : Although half the problems (the unfamiliar condition) in the qualitative inference task were true inference problems (involving either an unknown category or an unknown property), the other half (the familiar condition) only involved known categories and known properties (e.g. <u>All fire trucks have sirens. Do all trucks have sirens?</u>). These problems can be answered without any resort to deductive reasoning. Thus they cannot be considered as inference problems since nothing has to be inferred by the children, who could succeed simply by using their knowledge of the categories involved. In fact, 5- and 7-year-olds performed significantly better in these problems than in the ones requiring deductive reasoning. Three-year-olds performed at chance level in familiar and as well as in unfamilar problems while adults, relying on deductive reasoning, produced a comparable number of correct answers in both conditions. Not only were the results contaminated by problems that were inappropriate for the investigation of a deductive comprehension of inclusion, but, as in Smith's study, inferences requiring the understanding of transitivity and inferences assessing asymmetry were analyzed together, without distinction.

Comparisons between transitivity and asymmetry understanding in children were made by Greene (1989, 1991, 1994). Using a a property inference task, she investigated schoolchildren's construction of external representations (texts, drawings) of a hierarchy, and their capacity to use an existing adult representation of this hierarchy, a tree diagram, to guide their inferences about the properties held by the members of the hierarchy. The hierarchy studied consisted of a new and imaginary domain of knowledge: "Creatures from outer space" called Imps. In the presentation of Imps of different hierarchical levels, common properties were repeated at each level, making it clear that a property held by a given class of Imps was also held by its subclasses (Greene, 1989, 1991, 1994). Being necessary with such an unusual material, a tree diagram representing the entire hierarchy was placed in front of the child and was used as a mnemonic aid. Because this precaution allowed for a good proportion of correct responses to inference questions in all age groups (7-, 9-, 11-year-olds) to come from a mere matching strategy rather than hierarchical reasoning (Greene, 1989), the results seem hardly generalizable. However, transitivity appeared to be acquired before asymmetry and comprehension of both notions seemed to undergo some changes from 7 to 11 years (Greene, 1989, 1991, 1994). Again, as in Johnson et al.'s study, the ability to make qualitative inferences appeared to occur at an older age than in Smith's study.

The indeterminacy issue. Although promising, the use of deductive inference questions to assess inclusion understanding brings up the problem of indeterminacy. In fact, this problem does not arise for class inferences meant to assess transitivity ("A dax is a rabbit. Is a dax an animal?"). But when it comes to asymmetry, the appropriate answer to the class inference question ("A pug is an animal. Is a pug a dog?") is necessarily indeterminate. It is well-known that until 9-10 years, children demonstrate a fragile understanding of indeterminacy and have difficulty to recognize situations in which there are no necessary conclusions (Byrnes & Overton, 1986; Horobin & Accredolo, 1989; Piérault-Le Bonniec, 1980; Pillow, Hill, Boyce, & Stein, 2000). Thus, in class inference tasks, the child's performance on asymmetry could be poorer than her performance on class inference questions meant to assess transitivity. This difficulty may explain why qualitative inferences have not been used intensively. Smith's (1979) use of the modal terms "have to" might have been motivated by the intent to overcome this indeterminacy problem (A pug is a kind of animal. Does a pug have to be a cat?). Although this solution made all inference questions determinate, it led to other problems due to the child's poor comprehension of modal terms. Johnson et al.'s (1997) choice not to use "have to" in their third experiment and to reintroduce it in their fourth experiment illustrates the researchers' dilemma of choosing the lesser of two evils.

In 1989, Greene mentioned that asymmetry questions could be difficult because of their indeterminate nature. She specifically designed the third experiment of her study to see if children's failure on asymmetry questions was due to their reluctance to say "can't tell" and presented, among other conditions, a multiple-choice test for questions on asymmetry (in which "can't tell" was one of the choices). Compared to a condition where they did not have such choice of answers, children did improve their performance on asymmetry questions (Greene, 1989). Surprisingly however, Greene never used this multiple-choice test in her subsequent studies (1991, 1994). Perhaps she felt that a child's reliance on a given "can't tell" response could have various meanings. Although the reluctance to answer "can't tell" was recognized by some authors (Braine & Rumain, 1983) as a possible bias against the expression of indeterminacy understanding by children, empirical evidence showed that the effect of this peripheral factor is too negligible to explain their difficulty on indeterminacy problems (Champaud, 1985; Falmagne, Mawby, & Pea, 1989; Fay & Klahr, 1996). Furthermore, accepting only "can't tell" responses can be too stringent a criterion.

A solution to the indeterminacy problem might be to consider the justifications given in indeterminate situations. Although justifications never reflect the child's reasoning (this reasoning is not necessarily explicit), they nonetheless provide a complementary information on the complex cognitive situation the child is dealing with and on the aspects capturing his attention. According to Smith (1993, 1997), justifications are particularly relevant to the evaluation of indeterminacy understanding. Besides, children are frequently asked justifications in studies on such a topic (Fay & Khlar, 1996; Pillow et al., 2000). However, few researchers did so when assessing children's qualitative appreciation of inclusion. Johnson et al. (1997) did not ask for any justifications. Greene (1989, 1991, 1994) asked the children to justify their answers but, as Smith (1979), she did not mention the types of justifications that were accepted as adequate ones for asymmetry. In 1994, she did not even score the justifications at all.

A review of the studies on children's understanding of certainty and uncertainty showed that the age at which children demonstrated such an understanding ranged from 4 to 10 years (Byrnes & Beilin, 1991). The variety of the tasks employed and of the skills required in these tasks explains this gap. Future attempts to determine the role of indeterminacy in children's performance on qualitative inference about inclusion should not only consider the justifications given in indeterminate situations but should ultimately tap the multiple skills (such as recognizing possible solutions, producing possible solutions, considering the probability of different possible solutions as equal, discriminating between sufficient/insufficient-information context allowing to draw a determinate inference; see Byrnes and Beilin, 1991 for a review) that were found to be related to the understanding of indeterminacy.

## Conclusion

Young children have taxonomic knowledge that does not necessarily develop through thematic relations. However, although much has been said about their taxonomic abilities, the extent to which they understand the inclusion relation between two categories is not yet clear (Markman, 1989; Johnson et al., 1997). Conflicting evidence about children's knowledge of inclusion comes primarily from the variety of tasks used, but also from different procedures or scoring techniques when using similar tasks. For example, scoring sometimes takes justifications into account and is sometimes based on answers only. A review of the literature seems to favor the consideration of justifications as a solution for facing the indeterminacy problem in qualitative inferences. Moreover, researchers wanting to assess the inclusion relation should opt for deductive inference tasks over inductive ones. Although inductive inferences can reveal some links or overlapping relations between categories of different hierarchical levels, these relations are not of the same nature as the logically determined inclusive relation. The deductive task ultimately used to assess inclusion could be either quantitative or qualitative. The present review stressed the critics formulated about the use of the quantification task by the Piagetian school as a tool for the assessment of inclusion. Since the alternative qualitative task also presents some methodological challenges linked to the intrinsic logical necessity of inclusion (some of the qualitative inferences asked for are necessary indeterminate), the quantification task may remain an appropriate methodological option that should not be discarded until it is experimentally compared to the qualitative inference task. A recent study (Halford, Andrews, & Jensen, 2002) evaluated children aged 3 to 6 on a qualitative inference task and on the quantification task. Although the performance at both tasks was not directly compared, results suggested that, when ensuring that the children's answers are really based on an inferential process, 5-year-olds do not show a good comprehension of the inferences that can be deduced from inclusive relations (called "between-level inferences"). A look at their findings showed that these children had a weaker performance in property inferences ($\overline{X}$ = 5.67, out of 16) than in the quantification task[7] ($\overline{X}$ = 3.46, out of 6) and that younger children performed at chance level. This speaks for the need to compare older children on qualitative and quantitative tasks, a comparison that may demonstrate another developmental ordering in the abilities assessed by these tasks. Such a comparison is currently under investigation.

In any case, both a qualitative or a quantitative evaluation of children's comprehension of inclusion have to take into account the logical nature of inclusion. The superiority of one task over the other as an assessment tool to evaluate this comprehension may lie elsewhere. While the quantification task principally assesses the understanding of the asymmetric component of inclusive relations, a qualitative task provides the advantage of assessing transitivity and asymmetry separately and might thus offer a finer analysis of the acquisition of inclusion.

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Footnotes

[1] See Blewitt & Krackow (1992) for an experimental criticism of Nelson's mechanism of taxonomic category formation.

[2] See Piaget (1977) for a complete description of the acquisition of inclusion and for an account of the mechanisms (empirical and reflective abstractions) responsible for its development.

[3] However, in Farrar, Raney and Boyer's study (1992), preschoolers relied equally on appearance and category membership to make inferences.

[4] This procedure was modeled after Smedslund's one (1964).

[5] Other factors also contribute to category-based induction. See Lopez et al. (1992) for a presentation of the basic principles underlying this phenomenon.

[6] Hierarchies are also based on another principle which manages the horizontal relationship between categories, the contrastive principle (see Waxman, 1991b).

[7] Hodkin's (1987) class inclusion task was used.

# Chapitre 3

## Article 2

## The assessment of children's understanding of inclusion : Transitivity, asymmetry, and quantification.

Joane Deneault & Marcelle Ricard

(soumis)

# The assessment of children's understanding of inclusion relations: Transitivity, asymmetry, and quantification.

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# The assessment of children's understanding of inclusion relations: Transitivity, asymmetry, and quantification.


## Abstract

This study investigated the development of the understanding of class inclusion in children of 5, 7 and 9 years, whose performance on a qualitative class inference task assessing their appreciation of the transitive and asymmetrical nature of inclusive relations within the animal domain, was compared to their ability to make quantitative inferences in Piagetian class inclusion problems. Results showed that, although 5-year-olds demonstrate a fair knowledge of the transitivity of inclusion relations, this notion is not fully understood until the age of 7. In contrast, the process leading to the acquisition of asymmetry understanding appears relatively slow, and is not yet completed by 9 years of age. While the ability to make qualitative inferences requiring the understanding of transitivity is acquired well before the ability to make quantitative inferences, making qualitative inferences requiring a knowledge of asymmetry is as difficult as making quantified judgments. Methodological considerations about the complementarity of the two kinds of tasks, along with the theoretical implications of our findings for Blewitt's developmental model of hierarchical knowledge, are discussed.

In 1989, Blewitt proposed a model of the developing knowledge of categorical hierarchies in children. Assuming that such knowledge is not an "all-or-nothing" acquisition but a continuum within which different levels of understanding take place at different moments in the course of development, the model, which has undergone some changes since its creation, is now composed of three levels. At level 1, children (at 2-3 years of age) are able to form categories at different levels of generality and to include the same object (e.g. Fido) into multiple categories at different levels of generality (in the dog category as well as in the animal category). Level 2 is attained when children make qualitative inferences (inductive and deductive) about novel objects. For example, when told that a dax is a dog, they can infer that a dax is an animal. At this level, children should know that categories are connected in some way and should make inferences based on this knowledge. Finally, at level 3, children should be able to make quantitative inferences about the relative size of sets of objets that are vertically connected in the same hierarchy, i.e.they should succeed at Inhelder and Piaget's (1967) quantified class inclusion task. First proposed as a working hypothesis on the formation of categorical hierarchies, Blewitt's model was not submitted to a rigorous empirical verification, except for its first level (Blewitt, 1994). In a first attempt to distinguish between Blewitt's levels 2 and 3, Bruderlein (1993) compared the performance of 6-, 8- and 10-year-old children at inference tasks and at the Piagetian quantification task. However, because quantifiers ("some", "all") were included in the inference questions, these questions were not qualitative, so that the results could not verify Blewitt's hypothesis on the developmental distinction between level-2 ability to make qualitative inferences and level-3 ability to make quantitative inferences. In fact, Bruderlein concluded that inference problems with quantifiers appeared harder to solve than the quantification task. So the extent to which these two levels are distinct remains unknown.

The belief that children know something about inclusion and hierarchical relations before they can pass the traditionally criterial quantified class inclusion task at about 7-8 years is not new. As Blewitt (1989) argued, it was implicit in the Piagetian view. The classical Piagetian method of evaluating the child's taxonomic knowledge was not based solely on the class inclusion task but also involved another task, the classification task, in which the child's classifying strategies recaptured the entire developmental sequence from thematic to taxonomic organization. This was explicitely stated in Piaget's later writings (Piaget & Garcia, 1987) on intensional logic, a form of logic that develops earlier than the extensional logic of the operational child, and that accounts for the younger children's primitive understanding of inclusive relations well before they can succeed at the quantification of inclusion.

Most of this movement about a primitive understanding of inclusion originally came from critical accounts of the Piagetian tasks traditionally used to evaluate children's knowledge of hierarchies. On the one hand, the classification task was judged inappropriate because it fosters children's tendency to construct scenes and thematic designs. Reducing the saliency of the spatial aspect of the task (letting children sort the figures in transparent bags rather than on the table) increases their capacity to sort taxonomically (Markman, Cox, & Machida, 1981). On the other hand, the quantification of inclusion task, considered as the criterion for assessing "true" understanding of inclusion in children, was judged too difficult. Some neo-Piagetian researchers (Halford, 1987; Pascual-Leone, 1987- see Houdé, 1992 for a direct application of Pascual-Leone's theory to the class inclusion task) suggested that the quantification task puts the child in a misleading situation where he has to inhibit an attractive scheme (comparing the two subclasses with one another) in order to succeed. Markman (1989; Markman & Callanan, 1984) claimed that the task requires logical competencies that are not necessary for the comprehension of class-inclusion hierarchies. In one class inclusion problem, for example, the child was presented with five roses and three daisies and asked whether there were more roses (subset) or more flowers (inclusive set). In the traditional Piagetian perspective, a correct answer to this quantification question requires the reversibility of operations, for the child must be able to simultaneously conserve the superset while maintaining the identity of the subset. Although many experimental attempts were made to make the task easier (see Bideaud, 1988; Winer, 1980, for reviews), they have yielded mixed results : In some studies, the enhancement of class inclusion performance was exactly at chance level (leaving no means to distinguish it from mere guessing), in others it happened to be an artifact, or similar methodologies gave opposite results (Cormier & Laurendeau-Bendavid, 1982; Winer, 1980). Other adaptations of the class inclusion task (Shipley, 1979) still used today (Campbell, 1991) are suspected to bias children toward correct answering. In sum, if the class inclusion task assesses the understanding of inclusion at a concrete operational level, the use of another task could eventually demonstrate that children under 7 years of age do resort to a hierarchical organization of categories.

The methodological criticism of the traditional class inclusion task brought some researchers to look for alternative methods in assessing the understanding of inclusion relation. Markman (1989) proposed to evaluate the understanding of the inclusion relation that united categories of a hierarchical organization by tapping the two principles on which it stands: transitivity and asymmetry. A hierarchical system is composed of a number of categories or classes which are more abstract at the top of the hierarchy than at the bottom. Given that the vertical relationship between two classes is one of inclusion, that is, the lower level classes are included in upper level ones, transitivity means that if members of a class A (dogs) form a subclass of class B (mammals) and if members of class B form a subclass of class C (animals), then members of class A are necessarily members of class C. Vertical relations are also asymmetric in that all members of a class A (dogs) are members of a superior class B (mammals) but the reverse is not true: all members of a class B are not members of a class A. Thus, since inclusive membership that defines the vertical relation between classes rests on transitivity and asymmetry, the evaluation of the understanding of this inclusive membership should be based on the evaluation of transitivity and asymmetry comprehension. Markman's hypothetical considerations thus suggest that the understanding of transitivity and asymmetry should precede the ability to succeed in the Piagetian inclusion task.

Few studies have been designed to investigate children's understanding of transitivity and asymmetry of class inclusion relations (Markman, 1989). Harris (1975) did test it with 5- to 7-year-old children but conclusions were hard to draw since, for one thing, the results were not reported according to age. The most direct effort to evaluate children's understanding of transitivity and asymmetry came from a controversial study by Smith (1979), who proposed an ingenious deductive task in which children had to make qualitative inferences. Contrary to the Piagetian class inclusion task, these inference questions were meant to assess inclusion understanding without any recourse to quantitative reasoning. Although frequently quoted (Blewitt, 1989, 1994; Campbell, 1991, 1992, 1994; Markman, 1989) as an empirical support for early understanding of inclusion in 4-year-old children, this study suffers from methodological problems and presents incomplete data analysis. For one thing, the analysis did not provide any information about the relative difficulty of transitivity and asymmetry. Children's justification patterns were analyzed for transitivity problems but justifications were not even identified for asymmetry. Moreover, Smith observed order effects which were caused, among other things, by a too long period of questioning.

In the only replication of Smith's experiment, Johnson, Scott, and Mervis (1997) found that even though 3-year-olds showed a rudimentary knowledge of the asymmetry of inclusion in their inductive patterns (a task that was not used by Smith), generally, 5- and 7-year-olds still had many difficulties. They concluded that knowledge of inclusion remains fragmentary until after 7 years of age and that a general qualitative shift in children's understanding of inclusion relations is likely to occur after this age. Althought the appreciation of inclusion was assessed through qualitative inference questions, transitivity and asymmetry understanding were not investigated separately.

Greene (1989, 1991, 1994) did compare the comprehension of transitivity and asymmetry. In a series of studies, she investigated schoolchildren's construction of external representations (texts, drawings) of a hierarchy, and their capacity to use an existing adult-representation of this hierarchy, a tree diagram, to guide their inferences about the properties held by members of the hierarchy. The hierarchy studied consisted of a new and imaginary domain of knowledge: "Creatures from outer space" called Imps. Results showed that the mean proportion of correct responses to property inference questions increased significantly between 7;9 and 11;11 years for inferences based on both transitivity and asymmetry (Greene, 1991). As in Johnson et al.'s study, the ability to make qualitative inferences seemed to occur at an older age than it first appeared in Smith's study. Second graders (7;9 years) correctly answered only 57% of the inference questions on transitivity and 39% of the questions on asymmetry (Greene, 1991). A direct comparison of transitivity and asymmetry understanding showed that, in this task and with this material, asymmetry was more difficult than transitivity for 8- (1989) and for 6-year-olds (1994). However, because of the presence of a tree diagram placed in front of the subjects and used as a mnemonic aid (necessary with such an artificial material), a good proportion of correct responses to inference questions in all age groups came from a mere matching strategy rather than hierarchical reasoning (Greene, 1989). Moreover, only group results on transitivity and asymmetry were provided by Greene, making it impossible to know how the same child performed in these two respects.

Although theoretically promising, the use of qualitative inference questions to assess inclusion understanding brings up a methodological challenge: Some questions are indeterminate. In fact, this problem does not arise for class inferences meant to assess transitivity ("A dax is a rabbit. Is a dax an animal?"). But when it comes to asymmetry, the appropriate answer to the class inference question ("A pug is an animal. Is a pug a dog?") is necessarily indeterminate. It is well known that until 9-10 years, children demonstrate a fragile understanding of indeterminacy and have difficulty to recognize situations in which there are no necessary conclusions (Byrnes & Overton, 1986; Horobin & Accredolo, 1989; Piérault-Le Bonniec, 1980; Pillow, Hill, Boyce, & Stein, 2000). Thus, in class inference tasks, the child's performance on asymmetry could be poorer than her performance on class inference questions meant to assess transitivity.

Smith (1979) tried to overcome the disparity between transitivity and asymmetry by using the modal term "have to" in the questions she asked. In doing so, the inference questions meant to assess asymmetry became determinate too ("Does a pug have to be a dog?"). Although this method allowed that neither transitivity nor asymmetry questions were indeterminate, it might not solve the problem completely. First, children's understanding of modal expressions seems to be precarious. Three-, four-, and five-year-olds give similar responses to "has to" and "might" questions relative to indeterminate situations, suggesting that they do not appreciate the distinction (Byrnes & Duff, 1989). Even with 8- and 9-year-olds, the use of modal expressions such as "has to" does not reduce the difficulty in recognizing indeterminacy (Falmagne & al., 1989). Second, it seems that the modal questions used by Smith produced odd error patterns and made children respond poorly even to determinate items (see Smith, 1979, for a complete description of these patterns). Pilot work by Smith with questions that did not include modal terms did not produce these error patterns.

Noticing that asymmetry questions could be difficult because of their indeterminate nature, Greene (1989) specifically designed an experiment to see if children's failure on asymmetry questions was due to their reluctance to say "can't tell" and presented them, among other conditions, a multiple-choice test for questions on asymmetry (in which "can't tell" was one of the choices). Although this procedure did improve children's performance on asymmetry questions, Greene never used this multiple-choice test in her subsequent studies (1991, 1994). Although the reluctance to answer "can't tell" was recognized by some authors (Braine & Rumain, 1983) as a possible bias against the expression of indeterminacy understanding by children, empirical evidence showed that the effect of this peripheral factor is too negligible to explain their difficulty on indeterminacy problems (Champaud, 1985; Falmagne, Mawby, & Pea, 1989; Fay & Klahr, 1996).

Maybe part of the solution is to consider the justifications in responses to indeterminate questions. According to Smith (1993; 1997), justifications are particularly relevant to the study of indeterminacy. Children are usually asked for justifications in studies on indeterminacy (Fay & Klhar, 1996; Pillow et al., 2000). Although verbal justifications were found to fit well within the child's competence (Chapman & McBride, 1992) and provide rich information on her reasoning in quantified class inclusion problems (Richard & Leynet, 1994), few authors paid attention to them when assessing children's qualitative appreciation of inclusion. Even if some of their inference problems were indeterminate (the invalid scenario problems with an unknown category in experiment 3), Johnson et al. (1997) did not ask for any justifications and did not even mention the indeterminacy problem, scoring determinate and indeterminate problems together. Greene (1989, 1991, 1994) asked the children to justify their answers but she did not mention the types of justifications that were accepted as adequate for asymmetry and thus for indeterminate inference problems. In her 1994 study, she did not even score the justifications at all.

Another part of the solution may lie in the consideration of children's specific abilities related to indeterminacy. A review of the studies on children's understanding of certainty and uncertainty showed that the age at which children demonstrated an understanding of these concepts ranged from 4 to 10 years (Byrnes & Beilin, 1991). The variety of tasks employed to assess the comprehension of indeterminacy and the skills required in these tasks explained this gap. In spite of this, previous investigations (Fay & Klhar, 1996; Horobin & Accredolo, 1989) did establish that the capacity to recognize that a given problem has many solutions is a major acquisition in the understanding of indeterminacy. In children aged 5 to 12 years, the capacity to recognize and produce the possibilities in an indeterminate problem proved to be a prerequisite to the ability to make an indeterminate inference (Morin, 1992). So, in the class inference problems used to assess asymmetry, should the children have no difficulty to recognize or produce other alternatives than the one suggested in the inference question, one could conclude that the difficulty of asymmetry is lying more in its understanding per se than in its indeterminacy component.

The aim of this study was twofold: to compare children's performance on two methodological tools meant to tap the understanding of inclusion, i.e. the traditional quantified class inclusion task and a deductive inference task about category membership, and to provide an account of the developmental landmarks that lead to this understanding. To do so, the children's capacity to make qualitative inferences meant to assess transitivity and asymmetry understanding was compared to their performance on class inclusion questions that required them to make quantitative inferences (or reasoning). Moreover, we propose to scrutinize the effect of indeterminacy in qualitative asymmetry inferences by evaluating the child's capacity to recognize and produce alternative possibilities. These comparisons should determine if children are able to make qualitative inferences before they can make quantitative ones and should ultimately serve to define the boundaries between level 2 and level 3 in Blewitt's model.

## Method

### Participants

Seventy-two children took part in the study. They were equally distributed in three age groups: 5 years (Mean age = 5:7; SD = 0.28 month), 7 years (M = 7:7; SD = 0.3) and 9 years (M = 9:6; SD = 0.37). All came from the suburban area of Montreal, were from middle-class background and native French speakers. They all attended school and were respectively kindergartners, second graders and fourth graders[1]. Each group included an equal number of boys and girls.

### Tasks

Qualitative class inference task. Adapted from Smith (1979), the qualitative task comprised eight inference problems. Each problem presented an unfamiliar word (a non-sense label or an unknown word)[2] in a premise (A dax is a cat) followed by a deductive inference question (Is a dax an animal?). The relation between cat and animal was not given as in other studies (Smith, Johnson et al.). Three types of problems were presented: a) three inference

La description détaillée des tâches expérimentales de cette étude apparaît à l'Appendice A, section I.

problems evaluating the understanding of transitivity. These problems assessing the vertical relation between categories, always "moved" in a bottom-up direction within the hierarchy (e.g. Do you know what a dax is? A dax is a cat. If a dax is a cat, is a dax an animal?) and asked for determinate answers that could be logically deduced from inclusion relations. b) Three inference problems assessing the understanding of asymmetry. Also bearing on inclusion relations between categories vertically connected in the hierarchy, these inferences always proceeded in a top-down direction (e.g. Do you know what a pug is? A pug is an animal. If a pug is an animal, is a pug a dog?). These inferences were logically indeterminate. c) Two inference problems in which the categories were at the same hierarchical level and shared an horizontal relationship (e.g. Do you know what a dem is? A dem is a rabbit. If a dem is a rabbit, is a dem a pig?). These problems requiring negative answers did not assess inclusion understanding but were used to control response bias.

Inference questions were about the animal hierarchy. In Smith's class inference task, artifacts and natural kinds were both used but the performances were not compared. Yet natural kind categories are richly structured categories about which children were found to be less influenced by typicality effects and to take less time in judging category membership than with artifact categories (Cordier & Spitz, 1998). Even among adults, natural kinds are less graded and produce more agreement on category membership than do artifacts (Barr & Caplan, 1987). The animal category was chosen because it offers many exemplars which are well known by children: Most of the preschoolers' knowledge about the power of natural kinds is demonstrated for animal categories (Gelman, Coley, Rosengren, Hartman, & Pappas, 1998). Animals used in inference questions were all mammals and were chosen for their familiarity.

Contrary to Smith, the premise introducing the inference question did not contain the phrase "kind of" to present the link between the novel term and a given class. Experimental results showed that, although children could be sensitive to the inclusion information suggested by the phrase "kind of" during reference (Callanan, 1991; Golinkoff, Mervis, & Hirsh-Pasek, 1994), not all situations seem to elicit this sensitivity (see Callanan, 1989: exp. 1 and 2) making some authors (Callanan, Repp, McCarthy, & Latzke, 1994) abandon the use of "kind of" to convey inclusion information about two categories. Moreover, the use of "kind of" was found to promote learning of a new word "X" in preschool children but not its relation (supposedly inclusive) with a known word "Y": mutually exclusive interpretations were as frequent from children who were told that "X is a kind of Y" than from those who were told that "X is not an Y" (Diesendruck & Shatz, 1997). We observed a similar trend in our pilot work on 7-year-olds (n = 17, M= 7:6). In the "kind of" version of class inference problems, more children (75%) produced negative responses justified by mutual exclusivity (No, because these are two different kinds of animals) than in a version without "kind of" (44%). This phrase probably made children reason more about kind hierarchies (Shipley, 1989) than about class-inclusion hierarchies.

After each indeterminate inference question on asymmetry, children were asked a production question and two recognition questions. In the above-mentioned indeterminate problem with the "pug", these questions would have been: (Production question:) Can it be something else? What can it be? " (Recognition questions:) Can it be a squirrel? Why? Can it be a grape? Why?. One recognition question was about an impossible inference and served as a control to make sure the child did not simply give a positive answer to all questions.

The eight qualitative inference problems were presented in four different orders, each intermingling transitivity, asymmetry and control problems. Moreover, half of the children were assigned to a "no material condition", where no pictures were used, whereas the other half, in a "material condition", could see pictures of animals resting on the table throughout the task. These conditions were added in order to see if the presence of visual material constitutes a facilitating condition in qualitative inference tasks. This issue raised by Smith was never investigated as such. Johnson et al. (1997) did not present any material except for fictitious categories and Greene, who also presented fictitious categories, always used material. In our material condition, the session started with an identification task, in which the child had to pick out any given picture that, according to him, was not an animal. The inference task only began when the child had stated that all the remaining pictures were animals.

<u>Quantitative inference task</u>. Three class inclusion problems were administered. In each one, colored pictures of items from two subclasses of the same hierarchy (e.g. rabbits and pigs) were shown to the child. The total number of items was always seven, five from one subclass called the major one and two from the other. It is now well known that the gap between the number of items from two subclasses must be minimal for the task not to become unnecessarily difficult (Bideaud, 1988). So the ratio here was similar to those in other studies: 5:2 (Bideaud, 1988; Campbell, 1991; Chapman & McBride, 1992) or 5:3 (Bideaud & Lautrey, 1983). The items were placed on the table in an intermingled manner proved to facilitate performance (Gold, 1987). The procedure designed by Laurendeau-Bendavid, Pinard and Boisclair (1985, see Larivée, Normandeau, & Parent, 2000) was adopted. This procedure, modeled after Inhelder and Piaget (1967), also contained facilitating versions of each problem that could be presented to the child who had failed the standard one. In the present study, only one such facilitating version was administered after the standard one. For example, in a given problem with 5 rabbits and 2 pigs, the child was first asked to answer two identification questions: <u>Could you tell me what is on the</u>

table? Could you show me all the rabbits? Could you show me all the pigs?[3]. Then the child was asked preliminary questions about the inclusion relation between each of the subsets and the superset (e.g. Are rabbits animals? Are pigs animals?). Finally, she had to answer the test question based on the quantification of inclusion (e.g. Are there more animals or more rabbits? Why do you say that there are more ...?). The two classes in the inclusion question were always presented in a counterbalanced order. For those children who failed this quantification question, the problem was partially repeated in a facilitating form where the preliminary questions stressed the relations between the categories. In the preceding example, the child was asked: Are all these rabbits? Are all these animals? If I take out all the rabbits, would there be anything left? If I take out all the animals, would there be anything left? Then, the inclusion question was asked again.

Procedure

All children were tested individually at their school by the first author, in a single session that lasted 15 to 30 minutes. The tasks were administered in a counterbalanced order: Half of the participants received the quantitative class inclusion task first, followed by the qualitative inference task, while the other half was presented the reverse order. Each session was audiotaped, and all the testing was done in French.[4]

Scoring

In the qualitative inference task, children received two scores: one for inferences assessing transitivity and one for inferences assessing asymmetry. Both scores were based on the number of problems successfully answered and justified as defined below.

Transitivity inferences. In determinate inference problems, affirmative responses which were correctly justified were given a score of 1. The following justifications (already identified by Smith, 1979) were considered as equally correct: a) repeating the given premise (Because you said a dax is a cat), b) specifying the missing premise (Because cats are animals) or c) both, i.e. giving the entire argument (Because you said a dax is a cat and cats are animals, so daxes are animals). A maximum total score of 3 (from 0 to 3) could be attributed to the child for her performance on transitivity problems.

Asymmetry inferences. In indeterminate inference problems, a response was scored as correct if the indeterminate nature of the situation was specified by the child either in her answer or in her justification. Thus the three following patterns were accepted as a correct "answer-plus-justification":

a) Answers that already stressed the indeterminate nature of the situation (-- A dem is an animal. Is a dem a zebra? -- It could be. -- Why could it be a zebra? -- Because you didn't say what animal it is).

b) Positive or negative answers accompanied by a justification that mentioned the indeterminate nature of the situation (No. Because it maybe another kind of animal or Yes. Because we don't know what kind of animal it is).

c) Children who positively answered the inference question (Is a dem a zebra?) and justified it without any spontaneous recourse to indeterminacy were asked a certainty judgment question (Are you sure that a dem is a zebra?). Children who answered this second question negatively and justified their answer (No, because it could be an other animal, we only know that it is an animal) were credited with a correct answer. So, both the children who answered this certainty question positively (which was surprisingly frequent) and those who correctly answered negatively but without giving a correct justification were considered as having failed. The maximum total score a child could get for asymmetry problems was 3.

Recognition and production questions. Children received a pass or fail (1 or 0) score for each recognition question (there were three recognition questions, one following each indeterminate question on asymmetry). A child who both answered the recognition question positively and rejected the impossible inference that served as a control, was attributed a pass score. Children were also given a score for their performance on each of the three production questions. Scores were defined as follows: producing no exemplar = 0, producing only one exemplar = 1, producing two exemplars or more = 2, and acknowledging that any animal can be an exemplar = 3.

Quantitative inferences. In the quantitative inference task (the Piagetian class inclusion problems), the coding was done according to the scoring method of Laurendeau-Bendavid's (1985) standardized scale.[5] Each child received a total score between 0 and 3 which was based on her answers, her justifications and the number of problems at which she succeeded.

The score 0 was attributed to the child who did not answer or answered incorrectly on two problems or more (out of three). Children in this category either did not provide any justification or gave nonsense justifications (Because my mother wants it). The score 1 was attributed to children who answered that the major subclass was more than the superordinate class for at least two problems (There are more rabbits). In their justifications, these children usually compared the two subclasses with each other rather than the major subclass and the superordinate class (Because there are 5 rabbits and 2 pigs). Children of this level always answered preliminary questions correctly. In Piagetian terms, their answers were intuitive but always justified. Children with a score of 2 were those who wavered between the intuitive answer of level 1 and the operational answer of level 3. This level also included children who, after giving what seemed a level 1 response, discovered the correct answer and gave it (and correctly justified it) till the end of the task. This discovery could occur at any given point in the task. The score 3 category included children who correctly answered the quantification question (i.e. the inclusive superordinate class was said to be more than the major subclass) and correctly justified it. Were counted as correct justifications those who referred to the superordinate class (e.g. <u>Because they are all animals</u>) or to the complementary subclass (e.g. <u>Because there are some pigs too</u>), or to both of them (e.g. <u>Because they're all animals and some are pigs</u>), or to all three classes at once (e.g. <u>Because the pigs and the rabbits are all animals</u>).

<u>Interrater agreement</u>

A second rater coded the responses and justifications to transitivity and asymmetry questions and to quantification problems on 25% of the transcripts from each age group. Reliability between coders (agreements/agreements plus disagreements X 100) reached 94.4% for transitivity questions, 96% for asymmetry questions, and 100% for quantification problems. Disagreements were resolved through discussion.

## Results

<u>Qualitative inferences</u>

A preliminary analysis revealed that subjects' gender and presentation order did not have any effect on both transitivity and asymmetry inferences. These factors were thus removed from subsequent analyses.

There were practically no errors on the horizontal-relationship problems which served as controls. Only one subject failed one of these problems.

<u>Transitivity inferences</u>. A 3(age) X 2 (material condition) ANOVA was conducted on the number of questions successfully answered and justified (out of 3), with age and material as between-subject factors. Because the effect of these factors was tested in a second ANOVA on

asymmetry inferences, Type 1 error was controlled for by the Bonferroni's procedure which set the level of significance at $p<.016$. Results showed a significant main effect of age, $F(2,66) = 9.30$, $p< .001$. The Tukey test on multiple comparisons showed that 5-year-olds ($M = 1.92$) correctly answered fewer transitivity questions than 7- ($M = 2.75$, $p=.004$), and 9-year-olds ($M = 2.88$, $p=.001$) who did not differ from each other. Thus, even if the younger subjects had a good performance on transitivity questions (see Table 1), transitivity understanding still had to undergo some changes. Effect of material did not reach significant level ($p=.020$). No interaction effect was found ($p=.154$).

A qualitative analysis of the frequency of the two types of justification – repeating the given premise (a justification that was considered primitive by Smith, 1979) or specifying the missing premise or the entire argument -- was made across age. It revealed that on the questions that were well answered and justified in the transitivity inference task (which comprised a total of 72 questions), 5-year-olds justified by repeating the given premise on 29 questions, while 7- and 9-year-olds used this justification on 23 and 11 questions respectively. In contrast, 5-year-olds produced justifications based on the missing premise in only 17 questions, compared to 7-, and 9-year-olds who respectively gave this justification of a more advanced type 43 and 58 times.

Asymmetry inferences. A 3(age) X 2 (material condition) ANOVA was performed on the number of asymmetry questions correctly answered and justified (out of 3), with age and material as between-subject factors. The corrected significance level of .016 was required. Again there was a significant main effect of age, $F(2,66) = 7.61$, $p = .001$,. the 9-year-olds ($M = 1.75$) performing significantly better ($p = .001$) than the 5-year-olds ($M = .46$). No other difference was found. There was no effect of material condition ($p = .359$) and no interaction effect ($p = .552$).

Although the majority of asymmetry questions were failed by the two younger groups, a qualitative analysis was done on the type of justification following a good answer in each age group. Patterns of "answer-plus-justification" where the child spontaneously stated the indeterminate nature of the situation were considered the most advanced type while other patterns were more primitive. Primitive justifications were given on 5 occasions by 5-year-olds, on 9 occasions by 7-year-olds and on 19 occasions by 9-year-olds, whereas advanced justifications followed answers on 6, 19 and 22 occasions for 5-, 7- and 9-year-olds respectively.

As seen in Table 1, younger children responded correctly to transitivity questions 63,8% of the time in the "material" and "no material" conditions taken together, when scores were based on both answers and justifications. However, we could have chosen to score the subjects' performance according to their answers only. In Smith's study, where this kind of "yes/no judgments" (without justification) was used, kindergartners were correct 78% of the time. Based on these yes/no scores, the proportion of transitivity questions correctly answered (the correct answer being yes) by our 5-year-old subjects reached 97.2% (and 100% for the two older groups). Regrettably, this scoring method not only provides no information about why the child accepted the inference, but it is inadequate for asymmetry questions where justifications often revealed that the child had some appreciation of indeterminacy. Logically, correct answers to asymmetry questions (<u>Given that a pug is an animal, is a pug a dog?</u>) are neither positive nor negative. Nevertheless, some authors (Markovits et al., 1996) thought that a negative answer should be viewed as the expression that the pug is <u>not necessarily</u> a dog, which would be a good argument. If this is the case, negative answers to these questions should have been taken into account. The extent to which negative answers are really signs of this elaborated reasoning remains to be documented. Negative answers could also be given by a child who thought that a pug is not a dog, nor a cat, nor a cow, nor any known animal since these animals already have a name. Driven by the mutual exclusivity constraint, this kind of answer which allows no "possible" to be found in the indeterminate situation is primitive and has nothing to do with the denial of a suggested necessity component in the question. An analysis of the justifications that followed our children's negative answers revealed that none (0%) of these justifications were of the elaborated type in the two younger groups. The mutual exclusivity justification followed a negative answer in 70.7% of the cases (29/41 questions) in 5-year-olds (50% in 7-year-olds, who responded negatively to two questions only, and 25% in 9-year-olds, who answered eight questions negatively). In fact, of all the answers collected, 57% of the kindergartners' were negative, compared to less than 12% in the two older groups. Since negative answers apparently did not convey indeterminacy knowledge, they should not count as good answers in a qualitative inference task like this one.

Quantitative inferences

An univariate ANOVA on the quantitative class inclusion scores showed a main effect of age, $\underline{F}$ (2,69) = 23.05, $\underline{p} < .001$. Multiple comparisons revealed a gradual increase of performance with age: 9-year-olds ($\underline{M}$ = 2.62) were better than 7-year-olds ($\underline{M}$ = 1.92, $\underline{p}$=.002) who were better than 5-year-olds ($\underline{M}$ = 1.25 $\underline{p}$=.004).

Qualitative vs quantitative inferences

One goal of the present research was to determine if qualitative inferences evaluating transitivity and asymmetry are easier than quantitative ones and if they can therefore serve as a better assessment method to acknowledge the understanding of the inclusion relation in young children. McNemar tests were used to compare performance across the tasks. The comparison of our subjects' performances in the transitivity and the asymmetry inference tasks indicated that the former was easier than the latter. Only one child failed transitivity and passed asymmetry while 33 children showed the reverse pattern, $\chi^2(1, N=72) = 30.12$, $p < .001$. Since these two qualitative inference tasks were not of equal difficulty, each of them was first compared separately with quantitative inferences. As predicted by Markman (1989), there were more children ($n=33$) who succeeded on transitivity questions and failed the quantified class inclusion task than the reverse ($n=2$), $\chi^2(1, N=72) = 30.42$, $p<.001$. However, no consistent pattern of differing performance between asymmetry and quantification inferences appeared, $\chi^2(1, N=72) = 0.18$, $p=.83$, suggesting that the relation between these two abilities may not be hierarchical. Moreover, even when controlling for age, performances on the quantification task and on the asymmetry inference task were significantly correlated ($r = .30$, $p = .012$).

Thus, transitivity and asymmetry questions did not seem of equal difficulty. That is why these two notions were analyzed separately. But the understanding of the inclusion relation requires a joint knowledge of transitivity and asymmetry. Data on transitivity and asymmetry were thus combined to see how many children succeeded at both tasks and if these children did or did not fail the quantification of the inclusion task. As can be seen in Table 2, most of the children ($n=49$) behave similarly in qualitative and quantitative inferences, either failing both or succeeding at both. The other children were equally distributed: 11 succeeded at the quantitative inferences only, and 12 at the qualitative inferences only. In other words, if we take the Piagetian class inclusion task to determine how many subjects understood the inclusion relation, we end up with 26 children out of 72. If, instead, we use the qualitative inference tasks, the number comes to 27 children (from which only 15 were the same).

Asymmetry understanding and indeterminacy

Analyses of qualitative inferences demonstrated that, compared to transitivity, asymmetry was a difficult concept to grasp for children. One important difference between these two notions lies in their assessment: Asymmetry inference questions are indeterminate whereas transitivity ones were not. The following analyses were conducted to explore the role of indeterminacy in asymmetry evaluation by determining the children's capacity to recognize a possible exemplar in the indeterminate situation and to produce such possible exemplars, two abilities which are constitutive elements of indeterminacy understanding.

First, analyses were conducted to evaluate the capacity to recognize and produce exemplars and its evolution with age. Two 3 (age) X 2 (material condition) ANOVAs were conducted, one on the mean scores at production and one on the mean scores at recognition, with age and material as between-subject factors. The material condition was of particular interest here, since the children could have been more proficient at recognizing or at producing exemplars in the material condition where many exemplars were already on the table just in front of them. Results on production performance indicated a significant main effect of age, $F(2,66) = 11.57$, $p < .001$, but no effect of material condition ($p = .46$). The Tukey test indicated that 5-year-olds produced less exemplars ($M = 0.7$) than 7- ($M = 1.32$, $p < .05$) and 9-year-olds ($M = 1.89$, $p < .001$). The difference between the performance of the two older groups did not reach significance ($p = .06$). Recognition performance followed the same pattern: results showed that the capacity to recognize varied with age, $F(2,66) = 12.91$, $p < .001$, and that there were no effect of material. The age effect was due to the difference ($p < .001$) between 5-year-olds and the two older groups who did not differ from each other. The capacity to recognize and to produce was not influenced by the presence of suggested exemplars.

A partial correlation between the mean score at recognition questions and the number of asymmetry questions correctly answered demonstrated that, even with age partialled out, the performance on recognition questions was related to the performance on asymmetric inference questions ($r$ =.39, $p$ = .001) but not to the performance on the transitive inference questions ($p$ = .23). This relation between the ability to answer the asymmetric inference questions and the ability to recognize a possible exemplar in these situations was further explored to address the hypothesis that it might not be simultaneous. As expected, it appeared that 22 children succeeded at recognizing the exemplars while failing asymmetry questions, but that only one child showed the opposite pattern, $\chi^2(1, N=72) = 19.2$, $p< .001$ (McNemar test).

The relation between the understanding of asymmetry and the ability to produce exemplars in indeterminate situations was also analyzed. Partial correlation coefficients were computed, age being held constant. Results showed a significant correlation of .37 ($p$ = .002) between the asymmetry and production mean scores. No correlation was found between production and transitivity ($p$ = .234). Transitivity was not correlated to asymmetry either ($p$ = .137). Although performances on asymmetry and production were correlated, they may constitute different abilities since only two children succeeded at asymmetry while failing production and 22 children showed the reverse pattern and produced at least one exemplar while failing asymmetry ($\chi^2(1, N=72) = 16.6$, $p< .001$).

Multiple regression analyses were conducted to determine whether age, abilities related to indeterminacy understanding, and quantification performance accounted for variance in performance on qualitative asymmetry inferences as measured by the number of questions correctly answered. The performance at quantification constitutes an evaluation of the child's understanding of asymmetry that does no require competences related to indeterminacy. So multiple regressions were used to lighten up the relative contribution of those three factors. In the first analysis with asymmetry as the criterion variable, age was entered first, followed by recognition and production, and quantification. Age accounted for 18% of the variance in asymmetry understanding ($\underline{R}^2 = .18$, $\underline{F}$ (1,70) = 15.59, $\underline{p} < .001$), recognition and production accounted for a further 14% of the variance, $\underline{R}^2$ change = .14, $\underline{F}$ (2,68) = 6.73, $\underline{p} = .002$, and quantification significantly accounted for an additional 6%, $\underline{R}^2$ change = .06, $\underline{F}$ (1,67) = 6.75, $\underline{p} = .012$. If the recognition-and-production factor was entered into the regression first, it accounted for 28% of the variance in asymmetry understanding, $\underline{R}^2 = .28$, $\underline{F}$ (2,69) = 13.64, $\underline{p} < .001$, and took up all the variance that was accounted for by age. If quantification performance was entered first, it accounted for 23% of the variance in asymmetry performance, $\underline{R}^2 = .23$, $\underline{F}$ (1,70) = 20.61, $\underline{p} < .001$. These results suggested that the child's ability to make a qualitative inference honoring the asymmetry of the inclusive relation was highly predicted by her ability to both answer indeterminate questions and make quantitative inferences that do not involve any indeterminate component.

Error patterns: A glance at relations between categories other than inclusion

A closer look at the children's specific scores in the production task (see Table 3) showed a somewhat surprising pattern, especially for those children who produced only one exemplar: Half of them failed asymmetry and the other half succeeded. This special status of "producing one exemplar" becomes easily explainable when one considers the individual patterns of responding, including error patterns, in situations evaluating asymmetry. Error patterns in the indeterminate situations were found in a large number of children ($\underline{n}$=51). These patterns were based on the child's responses and justifications at the three questions pertaining to each indeterminate situation evaluating the understanding of asymmetry, i.e. the asymmetry inference question per se, the production question and the recognition question. One specific profile was attributed to each child. Most children (n=59) had the same pattern in all three indeterminate situations. For the others, a pattern had to appear in two situations out of three to be attributed to them: Four children met this criterion. But, because indeterminate situations are particularly difficult, nine children tried at least three different strategies, and were transferred in a non-classifiable category.

An interrater agreement between two independent judges was calculated on 25% of the transcripts from each age group. Reliability between coders (agreements/agreements plus disagreements x 100 ) was 89% and the Kappa coefficient for agreement was significant, $k$ = 0.858, $p < .001$. Disagreements were resolved through discussion.

As shown in Table 4, there were five patterns of responses: One was the adult pattern, all the others consisted in error patterns. The adult pattern was attributed to a child who understood the inclusion relation between categories. Children with this pattern succeeded at asymmetry questions and were aware of the indeterminacy of the situation; their number increased with age. The error patterns were particularly relevant in that they showed relations, other than inclusion, that can take place between two categories[6]. Although primitive, these patterns followed some logic for the child who struggled with the indeterminate situation, and they certainly had something to tell on the child's representation of relations between categories of different hierarchical levels. In the present experimental setting, the child had to interpret a new word like "pug" (presented in the premise <u>A pug is an animal</u>) in order to answer the inference question (<u>Is a pug a cat?</u>). Four types of erroneous interpretation of the new word were identified. 1) Some children considered that the "pug" was a new, yet <u>unknown</u> animal. This interpretation brought them to refuse all known animals as a "pug". Consequently they failed asymmetry, recognition and production questions. 2) The second profile was typical of children who assumed that the "pug" was a specific known animal which, most of the time, was the first animal about which they were asked questions. It was as if these children made a direct identification with the first animal they encountered. When told that a "tiv" was an animal and asked if a "tiv" was a camel, they stated that it was, but did not accept that the tiv could be any other animal. They thus failed recognition and production questions. Even though they accepted the inference that "a tiv is a camel", these children failed the asymmetry question for various reasons. They always failed to justify their answers (they either gave no justification or gave an inadequate one like Because it has two humps in the aforementioned example), and they clearly did not grasp the indeterminacy the situation conveyed. Some of them did accept that the "tiv" could be an animal very similar to the one in the inference question (e.g. a dromedary), but because their reasoning was based on an argument very similar to the identification just described, these children ($n$=4) were put in the same category. Half of them resorted to both arguments on different occasions (accepting two similar animals once and only the first identification in the other questions), thus leaving no doubt about the common logic of these arguments. Still, the majority of children in this category stuck to the first animal they had heard of. 3) Other children took the tiv to be a synonym for animal, therefore accepting to make the inference but failing to grasp the indeterminacy aspect of the situation. In fact, the situation did not convey any uncertainty for them, so they correctly recognized all the exemplars proposed by the experimenter and produced others as well. 4) Finally, a fourth pattern consisted in the term "pug" being granted some sense only with classes of animals comprising subclasses. For example, the "pug" could be a dog or a cat, because there are kinds of dogs and cats and the term "pug" could refer to those subclasses. But the "pug" could not be a sheep since there were no kinds of sheep for children. If the animals in the asymmetry question and in the recognition question did have subclasses, children of this profile did well; if not, they failed, and their answers to production questions always involved animals with subclasses.

The analyses of individual patterns of responses first suggested that some relations between categories of different levels are formed by the majority of children who do not fully understand the inclusion relations. Moreover, these relations do not seem to be developmentally equivalent. For instance, the interpretation of the unknown word as a synonym for "animal" seemed to be a more advanced strategy than its interpretation as an unknown animal. Primitive strategies like the unknown-animal or the identification-with-only-one-animal interpretations are probably driven by the mutual exclusivity constraint, while the synonymy interpretation could be the result of a biconditional understanding of the premise.

## Discussion

Our data suggest that Markman (1989) was partly right in proposing that transitivity and asymmetry are better measures of inclusion relation understanding. On the one hand, this tool did permit to identify children who understood something about inclusion relations but who could not be identified otherwise because of their failure on the standard quantification task. By 5 years of age, a majority of children in this study understood that if a given unknown thing is said to be a rabbit, it is an animal. They were thus able to make a qualitative inference based on the transitivity of inclusive relations. Yet, however good these young children may have been, their 7-year-old peers were still ahead. The comprehension of transitivity did not undergo any change over 7 years and seemed complete by then. As expected by Markman, these qualitative inferences were easier than the quantitative requirements of the Piagetian class inclusion task. On the other hand, even though transitivity was definitely easier for children than quantification, asymmetry understanding, as measured by qualitative inferences, was not. Like Blewitt (1989) suspected, the notion of asymmetry happens to be far more difficult than that of transitivity. Our results showed that these two notions followed different developmental paths. Contrary to the inference questions on transitivity, most of the inference questions requiring the understanding of asymmetry were failed by children of 5 (84.8% of questions failed) and 7 years (61.2%). This later development of asymmetry is in agreement with previous findings. In Johnson et al.'s (1997) study, participants aged 3, 5, and 7 years also showed a weak understanding of asymmetry, the adult participants being the only ones to show inductive patterns of responses demonstrating a more solid comprehension. In the present study, a large portion of the inference questions based on asymmetry were accurately answered by 9-year-old children. However, more than 40% of these questions were still failed. It would have been interesting to include older subjects in our sample to see how well they would have performed. Our results are also comparable to Greene's (1991). Using a facilitating procedure where children had a diagram of the entire hierarchy in front of them, this author nonetheless observed that 9-year-olds still failed 27% of the asymmetry questions. The asymmetry of inclusive relation seems to be a difficult concept to grasp and its understanding progresses slowly: The differences between our adjacent age groups did not reach significant level. Asymmetry understanding went through significant change only between 5 and 9 years of age.

This finding brings out two conclusions. First, it identifies additional milestones in the acquisition of inclusive relations in children. Also, it raises the issue of which methodological tools actually available is better suited for the assessment of asymmetry understanding.

The development of inclusion relation understanding in children

At the first level of hierarchical knowledge identified by Blewitt (1994), children of 2 and 3 years of age are not only able to form categories of different levels of generality but they can include the same object in two of these categories. At the second level, children are supposed to be able to make qualitative inferences, and should acquire the ability to make quantitative ones at the third level only. Our study demonstrated that, if there is to be a second level, it has to do with qualitative inferences that do not involve asymmetry understanding: The child, at this point, is acquainted with the transitivity aspect of inclusion relations without grasping the asymmetry component of this relation. For instance, 7-year-olds had a good performance in 92% of the inference questions assessing transitivity but they barely reached this level in 39% of the questions about asymmetry. Nearly all children in our experiment had more success in inference questions based on transitivity understanding than on both the qualitative inference task assessing asymmetry and the quantification task. The child's performance in qualitative inferences requiring asymmetry understanding happened to be highly correlated to her performance in the quantification task, but not to the qualitative inference questions about transitivity. These results showed that performances on the two kinds of qualitative inferences (transitivity, asymmetry) differed more than it was first suggested by Markman (1989) and Smith (1979). They also confirmed the findings of Greene (1989, 1991, 1994) who observed that children had greater difficulty with asymmetry than with transitivity. The fact that Greene asked questions about a fictitious material while we did so for the animal domain suggests that this developmental gap between transitivity and asymmetry may be generalizable to other domains as well. Indeed the performance on inference questions assessing inclusion did not appear to be highly vulnerable to domain effects. Bruderlein (1993) did not find any domain effect on the responses of 6- to 10-year-old children to quantified inference questions about inclusion. In fact, the performance remained the same whether the questions were asked about animals, fruits, vegetables or flowers. In light of our data, the central acquisition of level 2 (within Blewitt's model) should rather consist in the ability to grasp the transitive component of the inclusion relation than in a general ability to make all kinds of qualitative inferences. Therefore, level 3 would be better characterized by the understanding of asymmetry than by the capacity to make quantitative inferences. Understanding asymmetry implies that the qualitative inferences in a hierarchical system are unidirectional and that higher-order classes are larger than any of their constituent classes (Waxman, 1991b). Whether the acquisition of asymmetry should be evaluated by qualitative or by quantitative inference tasks will be discussed later, but whatever this choice shoud be, these tasks seem to be developmentally equivalent. Recent findings by Halford, Andrews and Jensen (2002) support this point. Although they used property inferences and did not distinguish between transitivity and asymmetry, Halford et al. (2002) also concluded that deductive inferences and the standard class inclusion task may assess the same concept.

Actually, level 2 has nothing to do with asymmetry comprehension and is distinct from level 3. But one could ask: Is there a need for a level 2? It is possible that the skills observed by Blewitt at level 1 (making categories of different levels and including the same object into two of these) emerge at the same time as the understanding of transitivity. Future research should verify this issue with children between 3 and 7 years of age. Although our study was primarily aimed at defining the boundaries of level 2 and level 3, the fact that the understanding of transitivity goes through some evolution until 7 years of age suggests that transitivity understanding may not be an acquisition synchronous with level 1 skills.

<u>How to measure asymmetry understanding</u>

Is qualitative inference assessing asymmetry a better methodological device than the Piagetian quantification task? In the search for an appropriate tool, two criteria must guide one's choice: the simplicity of its use and the extent to which it provides the information that is looked for, i.e. children's knowledge about class inclusion.

As a methodological tool, the qualitative inference task is not an easy one to use. The administration and scoring of qualitative inference responses and justifications to asymmetry questions is a long process. The fact that Smith did not even identify the kinds of justifications following the answers at asymmetry inference questions is probably not beside this point. However, as a first attempt to classify children's deductive ability to consider the asymmetry of inclusion, the categorization we made of our subjects' justifications certainly embraces the scope of the justifications they actually gave. Above all, it lets them some room to express their thought about complex situations as indeterminate ones. Many children in our sample would have been identified as having failed asymmetry questions if only their answers had been taken into account.

In our view, the main difficulty of the qualitative inference task lies precisely in the fact that, deductively, there is no "good answer" to its asymmetry questions because they are indeterminate. Its use, though, calls for a specification of the role of indeterminacy in asymmetry understanding. Among the solutions proposed by researchers, few if any were flawless. Whether one considers Smith's use of modal terms, Johnson's use of inductive inferences or the joint use of deductive inference and indeterminacy measures as we did here, none of these attempts to deal with the indeterminacy problem seems quite satisfactory. The present experiment resorted to two solutions : 1) asking for justifications with indeterminate questions, and 2) verifying the status of two essential abilities inherent to the understanding of indeterminacy, the ability to recognize possible answers in indeterminate situations, and the ability to produce such answers. On the one hand, those abilities were found to account for a significant part of asymmetry understanding. On the other hand, they were not the only important predictors identified: the children's performance at quantification (a measure of asymmetry understanding that does not involve any indeterminate component) also accounted for some variance in asymmetry scores. Other analyses revealed that children's recognition and production capacities preceded their capacity to deal with asymmetry questions. Besides, children who interpreted the new word as a synonym of the category in the premise (29% of 7- and 9-year-olds), all correctly answered the recognition and production questions but failed asymmetry. These findings suggest that the competence required to succeed in asymmetry is not reducible to recognition and production abilities. However, our results also clearly indicated that the children's performance in asymmetry was colored by their capacity to deal with indeterminacy.

The interdependency between asymmetry and indeterminacy is due not to an artefact or a methodological bias caused by the task we chose but to the very nature of the concepts involved. The asymmetry of an inclusive relation affects the likeliness to deduce any inference in both senses of the relationship. In one sense, a deducible conclusion can be inferred while in the other it cannot. This latter situation is called indeterminate because no answers can be determined by logical necessity. All deductive inference tasks ask for a reasoning on necessity (Smith, 1997) and our task is not an exception : To answer our asymmetry inference questions, the child had to acknowledge that even if a dax, that was said to be an animal, could be a dog, it was not necessarily so. Some might argue that our results relative to the greater difficulty of asymmetry compared to transitivity are due to the fact that the evaluation of transitivity did not call for such a judgment on necessity. When asking if a new thing, that has been said to be a zebra, is an animal, one is not asking at the same time if this is necessarily the case.

This discrepancy between transitivity and asymmetry assessment could be bypassed by designing tasks that evaluate asymmetry understanding without its necessity component. Many researchers (Barouillet, 1989, 1992; Bideaud & Lautrey, 1983; Campbell & Jantzen, 1994; Cormier & Dagenais, 1983; Markman, 1978; Voelin, 1976) think that it is exactly what the quantification task of Inhelder and Piaget does. They claim that it is possible to succeed at quantification problems without understanding the logical necessity underneath the inclusion relation and that the "modification question"[7] that Markman (1978) added to the standard procedure better gauges the grasp of logical necessity. For others (see Smith, 1993 chapter 7, for an illuminating discussion on this topic), Markman's modification question may not assess anything more than the Piagetian standard problem does. Whether the standard quantification problem does assess the necessity of inclusive relations constitutes an issue that is not closed yet, but the points of view may not be as irreconcilable as they seem. Campbell and Bickhard (1986; 1992) alleged that the standard quantification task may assess an implicit understanding of necessity. However that may be, one thing remains: Either one assesses asymmetry without its necessity component, i.e. with inductive inferences questions (like Johnson et al.'s) where there is no deducible answer and where many factors other than category inclusiveness (like perceptual similarity) are implied in the inferential process, or one is interested in the logical relation of inclusion and assesses deductive reasoning on its asymmetry component and therefore also assesses "something" about necessity.

Another solution to diminish the discrepancy between transitivity and asymmetry assessment would be to ask necessity questions about the transitive reasoning : "Are you sure that this new thing which is a zebra is an animal?" "Another child, Fred, said that this new thing is not an animal, is it true? Could it be true? Can he say this?" These attempts however are not without risks. Not only are modal expressions difficult to master but certainty is not necessity and truth-value is independent from modality (given that the child acknowledges that Fred's answer is not true, this child's answer is compatible with logical necessity but it does not mean that her answer was based on this logical necessity) (Smith, 1997). In sum, although some requirements have been identified in the evaluation of logical necessity understanding (as the relevancy of justifications, see Smith, 1993, 1997), this acquisition has been recognized as a difficult one to evaluate and, unfortunately, deductive assessment of the inclusion through transitivity and asymmetry inference questions, as Markman's (1989) suggested, cannot spare the topic of logical necessity.

Although the qualitative inference task has some "zones grises" that are not perfectly tuned yet, and although it is not as easy to use as the quantification task, it offers appreciable advantages. First, the use of the qualitative inference task makes it possible to identify the children who understand both transitivity and asymmetry, i.e. children who understand the inclusion relation according to Markman's criteria but who fail the quantification task. In this experiment, 31.6% of children could not have been identified as understanding inclusion otherwise. Second, the qualitative inference task is useful to evaluate the understanding of the transitive aspect of inclusive relations, a competency that appears to emerge very early in the preschool years and that the quantification task does not tap. One word on the effect of material on performance in qualitative inference questions: In our experiment, this factor did not reach statistical significance. Nonetheless, a closer look at the results reveals that this variable should not be neglected for some age groups whose understanding is still fragile, particularly the 5-year-olds engaged in transitivity questioning or the 7-year-olds engaged in asymmetry questioning who tended to perform better in the condition without material. Pictorial support may not be optimal for eliciting a taxonomic and hierarchical organization. Previous findings revealed that a linguistic support favors more taxonomic answers and thus leads to a taxonomic organization of the world while a pictorial support tends to arouse a thematic organization (Houdé, 1992). Future research with these age groups should readdress the material issue in order to verify its robustness. Finally, the qualitative inference task opens a window on the child's representation of a hierarchy. Contrary to the quantification task which, if failed, tells nothing about the child's mind other than the fact that he or she does not understand inclusion, the elaborated patterns of answering required by the qualitative task inform us at least on the constraints that prevent the child from elaborating a hierarchical system based on inclusive relations. For some children, it seems that a hierarchy must be built under the control of the mutual exclusivity constraint that manages the relations between the categories. The knowledge of hierarchical connections in these children is too fragile to meet the requirements of a qualitative inference and they have to make wise tricks (like reducing the possible "instantiation" of a new animal to a still unknown animal) to preserve the coherence of their understanding of a hierarchy. Moreover, the qualitative task makes it possible to identify the types of relations, other than inclusion, that children establish between categories of different levels. Although some of these relations were hypothesized by Johnson et al. (1997) and observed in toddlers' or preschool children's performance in different methodological contexts (Callanan et al., 1994; Diesendruck & Shatz, 2001; Taylor & Gelman, 1989), no empirical reports observed such a wide range of primitive relations between categories in school age children's answers. For all these reasons, we firmly think that the qualitative inference task should be used to evaluate the understanding of inclusion relation. Should it replace the standard quantification task? In this study, only 29% of the children identified as understanding inclusion succeeded in the quantification problems. We do not know yet why some children failed the qualitative inferences while succeeding on the quantitative ones and some others showed the reverse pattern but Barouillet's (1992) discovery of two types of reasoners might be of some help. What we know is that the qualitative inference task should not serve as a substitute to the quantification task but be added to it as an indispensable complement to assess the understanding of inclusion.

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# Footnotes

[1] A series of pilot studies on children 4 to 9 years (n=84) were done in order to determine the age of children who would participate in the present experiment and especially the exact format of class inference questions in the qualitative task (among others, the presence of the modal form and of the "all" term in the questions, the French translation best suited for French-speaking children, etc.).

[2] Some of these unfamiliar words were borrowed from Smith (1979), others from Bruderlein (1993) and some were of our own invention.

[3] Again all animals used were mammals.

[4] French translations of the questions are available on request to the first author.

[5] This standardization was based on a sample of 497 French-speaking children between 4 and 12 years of age.

[6] See Johnson et al. (1997) for a discussion on non-inclusive relations between categories.

[7] “Could you make it so that there will be more cats than animals on the table?”

Table 1.

Percentage of Transitivity and Asymmetry Questions Correctly Answered and Justified for Each Age Group in Both (material and no material) Conditions.

| | Transitivity | | Asymmetry | |
|---|---|---|---|---|
| Groups | Material | No material | Material | No material |
| 5-year-olds | 47.2 | 80.5 | 13.8 | 16.6 |
| 7-year-olds | 86.1 | 97.2 | 27.7 | 50.0 |
| 9-year-olds | 94.4 | 97.2 | 55.5 | 58.3 |
| All age groups | 75.9 | 91.6 | 32.3 | 41.6 |

Table 2.

Number of Children who Passed or Failed Qualitative (transitivity + asymmetry inferences) and Quantitative Inference Tasks.

| | Quantitative task | | |
|---|---|---|---|
| Qualitative | Fail | Pass | Total |
| Fail | 34 | 11 | 45 |
| Pass | 12 | 15 | 27 |
| Total | 46 | 26 | 72 |

Note. N=72.

Table 3.

Mean Percentage of each Production Score as a Function of Children's Performance on Asymmetry.

| | Production Score | | | |
|---|---|---|---|---|
| Asymmetry | 0 | 1 | 2 | 3 |
| Fail (n=44) | 46.2 | 23.5 | 21.2 | 9.1 |
| Pass (n=28) | 5.9 | 22.6 | 47.6 | 23.8 |

Note. Scores 0, 1 and, 2 depended on the number of exemplars produced while a score 3 was attributed to the child who acknowledged that any animal could be an exemplar and therefore produced all possible exemplars.

Table 4. Distribution of Children as a Function of their Response Patterns in Indeterminate Situations and Age.

| | 5 years[a] | 7 years[a] | 9years[a] | Total |
|---|---|---|---|---|
| Response Pattern | | | | |
| Unknown animal | 13 | 1 | 0 | 14 |
| Identification with one animal | 4 | 4 | 2 | 10 |
| Synonymy | 2 | 8 | 6 | 16 |
| Classes comprising subclasses | 0 | 0 | 2 | 2 |
| Adult pattern | 3 | 8 | 10 | 21 |
| Non-classified | 2 | 3 | 4 | 9 |

[a] n = 24.

# Chapitre 4

## Article 3

**The effect of hierarchical levels of categories on children's deductive inferences about inclusion.**

Joane Deneault & Marcelle Ricard

(soumis)

# The effect of hierarchical levels of categories on children's deductive inferences about inclusion.

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Authors' note

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## Abstract

Although the hierarchical levels of categories have been recognized as a major factor of variation in categorical reasoning, few studies examined its effect on the understanding of inclusion. This issue was approached by varying the levels (subordinate, basic and superordinate) of categories involved in inference tasks assessing 5-, 7-, and 9-year-old children's understanding of transitivity and asymmetry of inclusive relations in the dog hierarchy. Children were administered a qualitative inference task and a quantitative class-inclusion task presenting different hierarchical levels. Results showed that the hierarchical levels of categories had no effect on children's performance in class-inclusion problems. In contrast, for qualitative inferences assessing asymmetry, not only did the children's performance vary with the hierarchical level of the categories involved but the children's sensitivity to these levels seemed to evolve with age. While 5-year-olds performed at floor level, the superordinate-to-basic relation led their 7-year-old peers to a better understanding of asymmetry, and therefore of inclusion, than superordinate-to-subordinate or basic-to-subordinate relations. As for the 9-year-olds, asymmetry was easier to master in both superordinate-to-basic and superordinate-to-subordinate relations than in the basic-to-subordinate relation. Children's performance in qualitative inferences requiring transitivity understanding was not affected by the hierarchical levels of categories. Though exploratory, these findings help to clarify the developmental steppingstones through which the child comes to grasp the difficult concepts of inclusion and asymmetry and give some indications on the constraints that may affect their acquisition.

Résumé

Reconnu comme un facteur de variation du raisonnement catégoriel, le niveau hiérarchique des catégories a été peu étudié quant à son influence sur la compréhension de l'inclusion. Afin de remédier à cette lacune, la présente étude a comparé les capacités inférentielles d'enfants de 5, 7 et 9 ans dans deux tâches servant à évaluer la compréhension de la transitivité et l'asymétrie des relations inclusives de la hiérarchie des chiens, lorsque le niveau hiérarchique des catégories impliquées varie (subordonné, de base ou surordonné). Les enfants ont complété une tâche d'inférences qualitatives et une tâche de quantification de l'inclusion présentant différents niveaux hiérarchiques. Les résultats montrent que le niveau hiérarchique des catégories n'a pas d'effet sur la performance à l'épreuve de quantification. Par contre, dans les inférences qualitatives évaluant l'asymétrie, non seulement la performance varie en fonction du niveau hiérarchique des catégories, mais la sensibilité de l'enfant à certains niveaux hiérarchiques évolue avec l'âge. Bien qu'à 5 ans la performance ait été trop faible pour permettre l'identification de niveaux hiérarchiques privilégiés, à 7 ans, les enfants comprennent mieux l'asymétrie pour l'inférence de la catégorie surordonnée à la catégorie de base que pour les relations surordonné-subordonné ou de base-subordonné. Les enfants de 9 ans ont obtenu une performance plus élevée à l'asymétrie pour les relations surordonné-de base et surordonné-subordonné que pour la relation de base-subordonné. La performance des enfants dans les problèmes requérant une compréhension de la transitivité n'a pas été affectée par le niveau hiérarchique des catégories. Quoique exploratoires, ces résultats précisent la séquence développementale menant à la compréhension des notions d'inclusion et d'asymétrie et fournissent des indices quant aux contraintes susceptibles d'en freiner l'acquisition.

## Resumen

Si bien el nivel jerárquico de las categorías ha sido reconocido como el factor más importante de la variación en el razonamiento categórico, son pocos los estudios que examinan su efecto en la comprensión de la inclusión. Este tema fue abordado, con la variación de los niveles (subordinado, básico y superior) de las categorías involucradas, en tareas diseñadas para la comprensión de niños de 5, 7 y 9 años de edad de la transitividad y la asimetría de relaciones inclusivas en la jerarquía del perro. Los niños fueron sometidos a una tarea de inferencia cualitativa y una tarea de cuantificación de la inclusión que presentaba diferentes niveles jerárquicos. Los resultados demostraron que, en la prueba de cuantificación, los niveles jerárquicos de las categorías no tienen efecto en el desempeño de los niños. Por el contrario, entre las inferencias cualitativas que evalúan la asimetría, el desempeño de los niños no sólo varía en función del nivel jerárquico de las categorías, sino que, también la sensibilidad del niño evoluciona con la edad a ciertos niveles jerárquicos. En tanto que el rendimiento de los niños de 5 años ha sido insuficiente para la identificación de los niveles jerárquicos privilegiados, los niños de 7 años comprendieron mejor la asimetría y, por lo tanto, la inclusión para una relación 'superior a básica' que para una relación 'superior a subordinada' o 'básica a subordinada'. Mientras que para los niños de 9 años la asimetría fue más fácil de comprender, tanto en las relaciones 'superior a básica' como en las relaciones 'superior a subordinada' que en la relación 'básica a subordinada'. El desempeño de los niños en

inferencias cualitativas que requerían comprensión de transitividad no fue afectado por los niveles jerárquicos de las categorías. A pesar de su naturaleza exploratoria, estas conclusiones ayudan a aclarar el proceso de desarrollo a través del cual el niño aprende difíciles conceptos como la inclusión y la asimetría y otorga algunos indicios de las restricciones que pueden afectar su adquisición.

# The effect of hierarchical levels of categories on children's deductive inferences about inclusion.

J. Deneault & M. Ricard

Most of the existing literature on inclusion focused on two-level hierarchies and did not tackle the effect that the hierarchical levels of the categories might have on the acquisition of inclusive relations between them. Standard hierarchies usually comprise categories of three hierarchical levels: the superordinate level (animal), the basic level (cat) and the subordinate level (tabby). Inclusion characterizes the relation between any two of those categories as it characterizes all vertical relations between categories of a given taxonomy. Known as a difficult concept to grasp for children, the notion of inclusion may develop step by step and first appear when specific hierarchical levels are considered.

Yet, in the field of ecological (or prototypical) categorization, which contrasts with the research tradition on inclusion (called logical categorization) in that it does not primarily focus on the inclusive relation between categories and the whole system made up of these related categories but rather on the formation of each category (Markman, 1989)[1], it is well known that levels of abstraction -basic, subordinate and superordinate- have different weights in children's general cognitive organization. Young children's vocabulary is largely made of basic-level terms -like dog and chair- which are used before terms of other levels (Blewitt, 1983; Johnson, Scott & Mervis, 1997; Poulin-Dubois, Graham & Sippola, 1995; Rosch, Mervis, Gray, Johnson, Boyes-Braem, 1976). Basic level has been identified as a privileged level of representation in children's taxonomic organization (Cordier, 1993; Markman, 1989), in lexical development (Callanan, 1989; Golinkoff, Mervis, & Hirsh-Pasek, 1994; Waxman, 1990), and even in concept formation with adults (Murphy & Smith, 1982). While some results suggest that children form basic-level categories before superordinate ones (Horton & Markman, 1980; Mervis, 1987; Mervis & Crisafi, 1982; Rosch et al., 1976) and that subordinate categories are even more difficult for them to learn than basic (Mervis, Johnson & Mervis, 1994) and superordinate ones (Mervis & Crisafi, 1982), other results reveal an alternative developmental sequence where superordinate categories are acquired before basic-level categories (Mandler & Bauer, 1988; Mandler, Bauer & McDonough, 1991; Mandler & McDonough, 1993, 1998; Poulin-Dubois et al., 1995). In sum, hierarchical levels seem to have a large influence in all cognitive processes involving categories. They were identified as a major factor in the child's performance on many tasks, from designating concrete objects of the world (Blewitt,1983; Cordier, 1983; Johnson et al., 1997; Macnamara, 1982; Mervis & Crisafi, 1982; Mervis, 1987; Rosch et al. 1976) to sorting liked objects (Poulin-Dubois et al. 1995; Saxby & Anglin, 1983), or categorizing objects (Horton & Markman, 1980; Graham, Baker & Poulin-Dubois, 1998 -see table 2, p.108-). However, few studies have examined the effect of hierarchical levels on the child's performance in tasks specifically designed to investigate inclusion understanding (Johnson et al., 1997).

Among the tasks meant to evaluate this understanding, the Piagetian class-inclusion problem is certainly the most famous. This task requires judgments on the relative size of a set of objects that are vertically connected in a given hierarchy. For example, the child is presented with two basic-level classes of objects from the same hierarchy, say apples and oranges, and is then asked whether there are more fruits (the inclusive set) or apples (the major subset). In general, the quantification question bears on the relative size of a basic- and a superordinate-level category. Cordier (1983) varied the hierarchical level of the classes of objects involved in the class-inclusion task: boats, flowers and fishes served as basic-level inclusive sets in some problems while fruits, vegetables and clothes were used as superordinate inclusive sets in other problems. The categories were classified as basic or superordinate according to the performance of 4-year-old children at a designating task (see Cordier, 1993, for more details on this procedure). The results showed that 6-year-olds performed better in class-inclusion problems when the inclusive set was a basic rather than a superordinate class. Cordier's interpretation suggested that children's efficiency in these problems varied with the accessibility of the inclusive set in their cognitive representation: the more accessible the level of the inclusive set (i.e. being at basic instead of superordinate level), the more likely were the children to grasp the inclusion relation in this task. However, these findings may be due to the differential knowledge children have about the domains implied in Cordier's study. The fact that children performed better at a quantification problem with fishes than with fruits could be explained by their more limited knowing about fishes than fruits. Knowing less about the various subcategories of the fish class, the children were not attracted by them in the quantification problem (after all, all these fishes are simply fishes). This bias favored the inclusive set which happened to be the correct answer.

Methodological procedures other than class inclusion problems can assess children's understanding of inclusion. Markman (1989) and Blewitt (1989) suggested that the evaluation of inclusion relations understanding should be based on direct questioning of the children's comprehension of transitivity and asymmetry of inclusive relations, rather than on their performance on the Piagetian problem. To answer questions on transitivity and asymmetry, the child has to make qualitative inferences that do not involve unnecessary quantitative reasoning as in the Piagetian task (Markman, 1989). Smith's (1979) study on the children's ability to draw class inferences and property inferences was the first significative attempt to use such qualitative inference tasks. In Smith's problems, the child was presented a new word in reference to a known category and asked to infer if this new thing belonged to a different hierarchical level category of the same hierarchy (A Jaffa is a kind of orange. Does a Jaffa have to be a fruit?) or she was presented a new property in reference to a familiar category and asked if this unknown property was true of a subset or a superset (All children have spleens in them. Do all little boys have to have spleens in them? Do all people have to have spleens in them?). Answering "does a Jaffa have to be a fruit" or "Do all little boys have to have spleens" in the forementioned examples, requires the understanding of transitivity, i.e. the comprehension that if something is an orange, and if an orange is a fruit, therefore, this something is a fruit. Understanding asymmetry refers to the fact that, in the spleen example, it is easier to answer the little boys question than the people-in-general question. Although some conditions in Smith's study would have allowed to analyze the effect of hierarchical levels on qualitative inferences (among them the fact that the property inference task involved three-level hierarchies), this analysis was not performed.

The other few studies (Greene, 1989, 1991, 1994; Johnson et al., 1997) that assessed children's understanding of inclusion with such qualitative inference tasks did not examine the effect of hierarchical levels either. Being aware that studies on the understanding of inclusion mostly assessed basic-superordinate relations, Johnson et al. (1997) adopted Smith's tasks to evaluate the children's knowledge about inclusion relations between basic and subordinate categories. Although Johnson et al. chose a promising approach by using multiple measures, i.e. inductive and deductive inference tasks to assess the children's understanding of inclusion, their findings did not yield a clear picture of the development of this understanding. Inference questions requiring transitivity understanding were scored indistinctly with questions requiring the understanding of asymmetry, despite the fact that these notions were proven to be of different levels of difficulty for children (Greene, 1989, 1994) Above all, Johnson et al.'s experiments provide no information on the effect that the levels of generality of each category could have on the understanding of inclusion: all tasks were about two-level hierarchies, basic-subordinate, that were not compared to other types of hierarchies (for example basic-superordinate or subordinate-superordinate).

Bruderlein (1993) assessed the understanding of transitivity and asymmetry in children aged 6 to 10 years and found that, until age 9, children showed a moderate to low understanding of transitivity. In class inference problems, transitivity was unexpectedly more difficult to grasp than asymmetry for all age groups. These findings, which contrast with Greene's previous study (1989) where inferences requiring transitivity were reported to be easier than those requiring asymmetry, may be explained by the use of quantifiers ("all" and "some") in the inference questions and by the well-known difficulty of children to interpret such quantifiers (Inhelder & Piaget, 1967; Smith, 1979). Moreover, Bruderlein did not evaluate the effect of hierarchical levels of the categories involved in the inferences.

Greene (1989, 1991, 1994) examined the children's comprehension of transitivity and asymmetry of inclusive relations within a four-level hierarchy. Primarily designed to evaluate schoolchildren's capacity to construct an external representation of a hierarchy (i.e. text, drawings) or to use an existing adult representation (i.e. a tree diagram) as a guide for their qualitative inferences about the properties held by the members of this hierarchy, these studies investigated a new and imaginary domain of knowledge: the hierarchy of some creatures from outer space called Imps. According to Greene's results, children found property inference harder to draw when requiring asymmetry understanding than transitivity understanding (Greene, 1989, 1994). Moreover, 11-year-olds tended to answer more transitivity questions correctly than 9-year-olds who in turn outperformed their 7-year-old peers. The same developmental pattern appeared for asymmetric questions (Greene, 1991). Unfortunately, Greene did not examine if the categories level of abstraction had any effect on transitivity or asymmetry problems. Even though the status of the four levels in the hierarchy of Imps may have not been comparable to the levels of hierarchies within non fictitious domains known by the child (what is the basic level when one talks about Imps?), such an analysis would have been interesting.

In sum, up to now, few studies were undertaken to verify the effect of hierarchical levels on the children's understanding of inclusion.

The aim of this research was to see if children better understand the inclusive relation when this relation bears on two specific hierarchical levels. The effect of hierarchical level on the understanding of inclusion was investigated in two ways. First, we examined whether the hierarchical levels have an impact on performance at a qualitative inference task by questioning children on the vertical relations between all hierarchical levels, subordinate-, basic- and superordinate- categories, of a three-level hierarchy. The assessment of inclusive relations took into account both their transitive and asymmetrical nature. Previous results (Deneault & Ricard, 2002; Greene, 1989, 1994) demonstrated that asymmetry is more difficult than transitivity and should be assessed separately. Differences due to hierarchical levels might help to determine if there are privileged levels for transitivity understanding and for asymmetry understanding, if these levels are the same for both, and to what extent the privileged status of these levels in the understanding of inclusion varies in children of different ages. The findings were expected to highlight the sequence by which children acquire the notion of inclusion by revealing if this notion is first understood by children when it implies two particular hierarchical levels.

The second way to study the effect of hierarchical levels on inclusion understanding was to verify Cordier's (1983) finding that performance at the quantitative class-inclusion problems is better with basic-level than with superordinate inclusive sets. The quantitative problems presented here examined the effect of hierarchical levels on inclusive relations in the same three-level hierarchy as in the qualitative task. Performance with the inclusive set at the superordinate level was compared to performance with the inclusive set at the basic level, and precautions were taken to insure that the subclasses involved in both problems were equally known by the child. If Cordier's results were due to a true hierarchical level effect and not to a domain-knowledge effect, the problem with a basic level inclusive set should be easier than the other. Since quantified class-inclusion problems assessed the understanding of asymmetry, children's performance in this task and in the qualitative questions on asymmetry were compared in order to see if there was a similarity in terms of privileged hierarchical levels in both tasks, thereby suggesting a kinship between them.

## Method

### Participants

Thirty-six children took part in the study. They were equally distributed in three age groups, 5 years (Mean age = 5:6; SD = .22 month), 7 years (M = 7:6; SD = .34) and 9 years (M = 9:6; SD = .29), each including an equal number of boys and girls, except for the younger group (5 girls and 7 boys). The participants came from the suburban area of Montreal and were native French speakers from middle-class background. They all attended school as kindergartners, second graders and fourth graders.

### Tasks

Qualitative class inference task. The qualitative task was a deductive class inference task inspired by Smith (1979). It included questions on the vertical relations between all hierarchical levels of the hierarchy of dogs. Many reasons motivated the choice of this specific hierarchy. Animals are natural kind categories and natural kinds are richly structured categories about which children were found to be less influenced by typicality effect, and to take less time in judging category membership than with artifact categories (Cordier & Spitz, 1998). Moreover, natural kinds of different hierarchical levels are usually labeled by different names, which is not necessarily the case with artifacts whose labels are often repetitive: trucks/fire trucks, chairs/rocking chairs. Such a

La description détaillée des tâches expérimentales de cette étude apparaît à l'Appendice A, section II.

repetition makes subordinates and basics closer to each other than basics and superordinates (see Diesendruck and Shatz, 2001 on a similar issue) and must be avoided especially when comparing the effect of hierarchical levels. Furthermore, most of the preschoolers' knowledge about the inferential power of natural kinds was demonstrated from animal categories (Gelman, Coley, Rosenberg, Hartman & Pappas, 1998). Dogs were especially chosen among other animals. A preliminary study on 17 children revealed that they knew more about the subordinate level of this hierarchy -subtypes of dogs- than about any other basic level category in the animal hierarchy.

The qualitative task demands a high level of attention. Results from Smith's study showed a presentation order effect: the second half of the problems were associated with a higher rate of failure. So in order to minimize the number of problems presented to the child, our task comprised eight inference problems (as in Johnson et al., 1997), that were of three types: problems on transitivity, problems on asymmetry and control problems.

Transitivity problems assessed the understanding of inclusion relations between categories that shared a vertical relation and always "moved" in a bottom-up direction within the hierarchy. The task comprised three transitivity problems that assessed the child's capacity to make an inference between different hierarchical levels: one problem was about the basic-to-superordinate level relation (e.g. <u>Do you know what a dax is? A dax is a dog. If a dax is a dog, is a dax an animal?</u>), another one was about the subordinate and the basic level category, and finally one was about the subordinate-to-superordinate level relation. Each unfamiliar or non-sense word[2], e.g. dax, was linked to only one known category. The order of presentation was counterbalanced. Correct answering to these problems demonstrated knowledge about the transitive nature of inclusion relations.

Asymmetry problems also assessed inclusion relations between categories that shared a vertical relation, but in a top-down direction within the hierarchy. Again, three problems assessed each possible relation between superordinate, basic and subordinate level classes and the presentation order was counterbalanced. For example, the basic-subordinate problem was Do you know what a dax is? A dax is a dog. If a dax is a dog, is a dax a Dalmatian?. Since the class inference questions assessing asymmetry are indeterminate, additional questions on the child's appreciation of indeterminacy were asked after each asymmetry question in order to investigate the role of indeterminacy in asymmetry inference performance. The capacity to consider that a problem had multiple solutions or possibles, the capacity to recognize such possibles, to produce them and to consider them as equal (Byrnes & Beilin, 1991; Fay & Klahr, 1996; Horobin & Accredolo, 1989; Morin, 1992) were recognized as key concepts leading to indeterminacy understanding. In the present study, questions evaluating children ability to produce the possible instances that could stand for the unknown word in the premise and to recognize these instances when presented to them were asked after the asymmetry question Is a dax a Dalmatian? : one production question Can it be something else? What can it be? and two recognition questions (recognition/test) Can it be a bulldog? Why? , (recognition/control) Can it be a sheep? Why?. This last question about an impossible inference served as a control to verify that the child did not simply give a positive answer to all the questions.

Two control problems in which the inference had to be made between categories at the same hierarchical level (and thus sharing an horizontal relationship) were also presented. One problem was about the relation between two subordinates (e.g. Do you know what a "X" is? A "X" is a Collie. If a "X" is a Collie, is a "X" a Beagle?) and one was about the relation between two basic levels (If a "X" is a cat, is a "X" a dog?). These problems did not assess inclusion understanding but were used to control response bias by asking the child questions that required negative answers.

The qualitative inference problems were presented in four different orders, each intermingling transitivity, asymmetry and control problems. In order to minimize the cognitive effort required in considering that there are many subtypes of dogs, pictures of dogs remained in front of participants throughout the qualitative inference task.

Quantitative inference task. Two class inclusion problems were administered. One used the animal class (a superordinate category) as the inclusive set and pigs and rabbits as its subclasses, while the other used the dog class (a basic category) as the inclusive set and two subtypes of dogs known by the child, for example terrier and beagle, as subclasses. In each problem, seven colored pictures of the items were shown to the child: there were five pictures from one subclass called the major subclass, (e.g. rabbits in the animal problem), and two pictures from the other (e.g. the pigs). The procedure designed by Laurendeau-Bendavid, Pinard and Boisclair (1985, see Larivée, Normandeau & Parent, 2000) was adopted. This procedure, modeled after Inhelder and Piaget (1967), contained facilitating versions of each problem that could be administered to the child who had failed the standard one. In the standard version, the child was first asked two identification questions: Here are some animals. Could you show me all the rabbits?

Could you show me all the pigs?. Then the child was asked preliminary questions about the inclusion relation between each of the subsets and the superset (e.g. Are rabbits animals? Are pigs animals?). Finally, she had to answer the test question based on the quantification of inclusion (e.g. Are there more animals or more rabbits? Why do you say that there are more …?). The two classes in the quantification question were always presented in a counterbalanced order. For those children who failed this quantification question, the problem was partially repeated in a facilitating form where the preliminary questions stressed the relations between the categories. In the preceding example, the child was asked: Are all these rabbits? Are all these animals? If I take out all the rabbits, would there be anything left? If I take out all the animals, would there be anything left?. Then, the quantification question was asked again.

Procedure

All children were tested individually at their school by the first author, in a single session that lasted 15 to 30 minutes. A pre-test identification task was first administrered to the child to investigate her knowledge of dogs. Pictures of subtypes of dogs were placed on the table and the child had to identify the ones she knew. Only dogs identified with a subordinate level label were used in the experimental tasks. The experimental tasks were then administered in a counterbalanced order: half of the participants received the quantitative class inclusion task first, followed by the qualitative inference task, while the other half was presented the reverse order. Each session was audiotaped, and all the testing was done in French.[3]

Scoring

In the qualitative inference task, children received a score for each inference question assessing transitivity and for each inference question assessing asymmetry. The score was based on the answer and the justification given by the child as defined below.

<u>Transitivity inferences</u>. Scores on transitivity could vary from 0 to 2 for each problem. A child whose answer was negative to the question (e.g. <u>A dax is a dog. Is a dax an animal?</u>) was attributed a score of 0. A score of 1 was given to the child whose answer was affirmative and justified by repeating the premise (<u>Because you said a dax is a dog</u>). A score of 2 was given to the child whose affirmative answer was completed by the missing premise (<u>Because dogs are animals</u> or <u>Because you said a dax is a dog and dogs are animals, so daxes are animals</u>).

<u>Asymmetry inferences</u>. Scores on asymmetry could also ranged from 0 to 2 for each problem. In these problems (e.g. <u>A dax is a dog. Is a dax a Dalmatian?</u>), a response was scored as correct if the indeterminate nature of the situation was specified by the child. Children whose answers spontaneously stressed this indeterminate nature (<u>It could be. -- Why could it be a Dalmatian? -- Because you didn't say what dog it is</u>) were given a score of 2. Positive or negative answers accompanied by a justification that referred to the indeterminate nature of the situation (<u>No. Because it maybe another kind of dog</u> or <u>Yes. Because we don't know what kind of dog it is</u>) were given a score of 1. Children who positively answered the inference question and justified it without any recourse to indeterminacy (<u>Yes. Because it's a dog.</u>) were asked a certainty judgment question (<u>Are you sure that a dax is a Dalmatian?</u>). Those who answered this second question negatively and justified their answer (<u>No, because it could be another dog, we only know that it's a dog</u>) were also credited with a score of 1. Children who answered this certainty

question positively, which was surprisingly frequent, were considered as having failed and were given a score of 0. All other answers received a score of 0.

Recognition and production questions. Children received a pass or fail (1 or 0) score for each recognition question (there were three recognition questions, one following each indeterminate question on asymmetry). A child who simultaneously answered the recognition question positively and rejected the impossible inference that served as a control, was attributed a pass score. Children were also given a score for their performance on each of the three production questions. Those scores were defined as follows: producing no exemplar = 0, producing only one exemplar = 1, producing two exemplars or more = 2, and acknowledging that any member of the premise category can be an exemplar = 3.

Quantitative inferences. In the quantitative inference task, the child received a pass or fail score for each problem. Success was determined by acknowledging that the inclusive class was greater than the major subclass and by giving a correct justification. Were counted as correct justifications those who referred to the inclusive set (e.g. Because they are all animals) or to the complementary subclass (e.g. Because there are some pigs too), or to both of them (e.g. Because they are all animals and some are pigs), or to all three classes at once (e.g. Because the pigs and the rabbits are all animals).

Interrater Agreement

A second rater coded the responses and justifications to transitivity and asymmetry questions and to quantification problems on 33% of the transcripts from each age group. Reliability between coders (agreements/agreements plus disagreements x 100) reached 94.4 % for transitivity questions, 91.6 % for asymmetry questions, and 100% for quantification problems. Disagreements were resolved through discussion after listening to the recordings.

## Results

Preliminary analyses revealed that subject's gender and presentation order did not have any effect. These factors were thus removed from subsequent analyses. One 5-year-old child justified all his answers in the qualitative inference task with "I don't know" and was thus excluded from further analysis. This child was the only one who failed both horizontal relationship problems used to hinder a bias in children responding. Otherwise, performance on these problems was high : Kindergartners correctly answered and detected 86.4% of these invalid inferences while second graders and fourth graders reached 95.8% and 100% of success.

### The effect of hierarchical levels on qualitative inferences

Two ANOVAs were first carried out to assess the effect of hierarchical levels on qualitative inferences. First, a 3 (age) X 3 (hierarchical levels) mixed ANOVA was done on the transitivity scores (see Table 1), with age as the between-subject variable and hierarchical levels as the within-subject variable. This analysis revealed a main effect of age, $F$ (2,32) = 10.5, $p < .001$, but no effect of hierarchical levels on transitivity performance ($F$ (2,64) = 0.75, $p = .46$). No interaction effect between these variables was found. The Tukey test showed that the 5-year-olds' performance on transitivity questions was poorer than the 7-, and 9-year-olds' ($p < .01$ and $p < .001$ respectively). The two older groups did not differ.

A 3 (age) X 3 (levels) mixed ANOVA was also conducted on the performance at asymmetry questions (see Table 2). Age had a significant effect on asymmetry performance ($F(2,32) = 9.39$, $p = .001$). The Tukey test showed that 7-year-olds and 9-year-olds did not differ from each other but significantly outperformed 5-year-olds ($p < .01$ and $p < .001$ respectively), who failed all the asymmetry questions. The ANOVA also yielded a main effect of hierarchical levels on asymmetry performance ($F(2,64) = 10.02$, $p < .001$)[4] and revealed an interaction effect between age and hierarchical levels ($F(4,64) = 2.85$, $p = .03$). The floor performance of the 5-year-olds prevented any hierarchical level effect at this age. However, the hierarchical levels involved in the inference had an effect on the 7- and 9- year-olds' performance at asymmetry ($F(2,22) = 5.02$, $p = .02$ and $F(2,22) = 6.34$, $p < .01$). Follow-up pairwise comparisons tested with the LSD procedure revealed that the differences between hierarchical levels were not the same for these two age groups. Seven-year-olds were more successful in the superordinate-to-basic level inference than in the superordinate-to-subordinate ($p < .05$) and the basic-to-subordinate inferences ($p < .01$), which did not differ from each other. In contrast, 9-year-olds did equally well in both the superordinate-to-basic and the superordinate-to-subordinate problems, but had a significantly lower score ($p < .01$ and $p < .05$) in the basic-to-subordinate problem.

The effect of hierarchical levels on quantitative inferences

A McNemar test was used to compare the child's performance (0/1) in the animal-problem where a superordinate class -animals- was the inclusive set and in the dog-problem where a basic class -dogs- was the inclusive set. The test revealed that hierarchical level had no effect. None of the children succeeded in one problem while failing the other. The performance at these two problems was exactly the same: children either correctly answered the quantification in both problems or failed both, and this for all age groups.

Analyses were also performed to verify if the quantification task and the asymmetry questions in the qualitative inference task, both evaluating the comprehension of asymmetry, resulted in similar performance. This analysis was done for the two specific relations between hierarchical levels that were available in both tasks: the superordinate-basic and the basic-subordinate relations. The McNemar test for the significance of changes revealed that, for basic-subordinate problems (dog-Dalmatian), more children ($N = 12$) succeeded at the quantification problem while failing the qualitative inference on asymmetry whereas only one child showed the opposite pattern ($p = .003$), suggesting that, for basic-subordinate relations, quantitative inferences were easier than qualitative inferences on asymmetry. By contrast, for superordinate-basic relations which are traditionally the levels used in the quantification task, the children's distribution showed no difference between the qualitative and the quantitative tasks.

Secondary analyses

Although both the quantitative and the qualitative tasks assessed children's appreciation of the asymmetry of inclusive relations, their performance was influenced by the hierarchical levels of categories only in the qualitative task. One difference between quantitative and qualitative questions about asymmetry lies in their determinate/indeterminate nature. Analyses on the children's capacity to recognize and produce the possible solutions of an indeterminate situation, two capacities directly related to the grasp of indeterminacy, were thus conducted to explore the part played by indeterminacy in asymmetry assessment with the qualitative task. If the problems children had with asymmetry questions were due to their indeterminate nature, what appears to be a differential effect of hirerarchical level on asymmetry could rather be an effect of hierarchical level on indeterminacy, some problems being more indeterminate than others in the child's view.

Multiple regression analyses were carried out to determine the part of variance in asymmetry performance accounted for by recognition and production. Age was entered into the regression first, recognition second, and production third. For the superordinate-basic relation, age accounted for 36% of the variance in asymmetry performance ($R^2$ = .36, $F$ (1,33) = 18.43, $p$ < .001), but when recognition ($R^2$ = .36, $F$ (1,32) = 0.8, $p$ = .78) and production ($R^2$ = .39, $F$ (1,31) = 1.46, $p$ = .24) were entered in the equation, there was no significant increase in $R^2$. The three predictors had a similar impact on the understanding of asymmetry in the superordinate-subordinate relation: age accounted for 28% of the variance in asymmetry performance ($R^2$ = .28, $F$ (1,33) = 12.53, $p$ = .001), while recognition ($R^2$ = .30, $F$ (1,32) = 1, $p$ = .33) and production ($R^2$ = .32, $F$ (1,31) = .9, $p$ = .36) did not offer additional predictive power beyond that contributed by age. However, for the basic-subordinate relation, recognition and production accounted for supplementary variance. Age accounted for 14% of the variance in asymmetry performance ($R^2$ = .14, $F$ (1,33) = 5.54, $p$ = .025), while recognition accounted for an additionnal 15% ($R^2$ = .29, $F$ (1,32) = 6.59, $p$ = .015) and production for an additional 10% ($R^2$ = .39, $F$ (1,31) = 5.03, $p$ = .36). These results suggest that the role of indeterminacy in asymmetry performance when evaluated by qualitative inference questions depends on the hierarchical relations considered. For superordinate-basic and superordinate-subordinate relations, children's performance on asymmetry questions was not predicted by their capacity to recognize and produce possible exemplars for the indeterminate situation. However, for the basic-to-subordinate relation, the capacity to recognize and produce an alternative exemplar, i.e. an animal other than the one presented in the premise, was particularly significant.

## Discussion

This study was designed to investigate the effect of the hierarchical levels of categories –subordinate, basic, superordinate- on children's understanding of inclusion when assessed by two procedures : a qualitative inference task and the quantitative class-inclusion task. Both tasks were presented to children of 5, 7 and 9 years in order to see if the potential effect of hierarchical levels on transitivity and asymmetry, two characteristics of inclusive relations, varied with age.

Our results showed that, for qualitative inferences meant to assess transitivity, hierarchical levels made no difference. Children's scores on transitivity questions were not different whether the inference had to be drawn from a basic (dog) to a superordinate (animal), from a subordinate (as Dalmatian) to a superordinate, or from a subordinate to a basic category. The high rate of success on these questions might have overruled potential differences caused by hierarchical levels that could eventually emerge with younger children. In our sample, children of all age goups did well on transitivity questions: 5-, 7- and 9-year-olds correctly answered and justified 60.6%, 80.6 %, and 94.4% of the questions. Even so, 9- and 7-year-olds had a better performance on these questions than 5-year-olds, indicating that the understanding of transitivity still develop until at least 7 years.

By contrast, performance on qualitative inferences assessing the asymmetry of inclusive relations between categories was sensitive to the hierarchical levels of those categories. The overall percentage of asymmetry questions correctly answered and justified fell down to 0%, 41.6%, and 58.3% from the younger to the older group. The poor performance of the 5-year-olds prevented any hierarchical level effect at this age to appear. But the performance of the two older groups showed interesting patterns: not only did their performance on asymmetry vary with the hierarchical levels presented, but the hierarchical levels that had a privileged status differed from one age to the other. For 7-year-old children, the asymmetry inference from a superordinate to a basic category was easier to draw than both inferences from a superordinate to a subordinate or from a basic to a subordinate category. In contrast, for 9-year-olds, the superordinate-to-subordinate inference was as easy as the superordinate-to-basic one and both were easier than the basic-to-subordinate inference. What differentiates these patterns? Seven-year-olds made more inferences from animal-to-dog than from animal-to-Dalmatian or from dog-to-Dalmatian. Thus it appears that, whatever the hierarchical level of the category involved in the premise, children were more reluctant to infer to a subordinate, than to a basic as if the key of this pattern lied in the level of the category at which the children had to infer. This pattern fits well with the performance that could be expected under the mutual exclusivity constraint, i.e. the assumption that each object has only one label (Markman, 1989; Markman & Wachtel, 1988). Children functioning under this constraint could not accept that a "dax" could be a Dalmatian because Dalmatians are already labeled Dalmatians. However, the mutual exclusivity constraint could have led the child to accept that a "tiv" might be a dog because there are several kinds of dogs, and maybe the tiv is just one of them. Two pieces of evidence support this hypothesis. First, some of our children did explicitly rely on such a rational to refuse an asymmetric inference ("Dalmatians are already named Dalmatians"). Second, previous findings also demonstrated that children tuned their use of mutual exclusivity as a function of the hierarchical informations conveyed by the situation, applying the bias to categories perceived at the same hierarchical level (like in the dax-Dalmatian example) but letting it down and assigning a second label to an object when the hierarchical level of this label could be perceived as different (Au & Glusman, 1990). Besides, in a recent study, Diesendruck and Shatz (2001) considered the frequencies of mutual exclusivity answers as an indicator of sensitivity to hierarchical information suggesting that hierarchical relations tend to compete with mutual exclusivity. Although the mutual exclusivity bias is well known for its role in word learning and category formation in young children (Markman, 1989; 1991; Merriman & Bowman, 1989), this bias was found to be more active in older preschoolers than in toddlers (Merriman & Bowman, 1989; Merriman & Stevenson, 1997) and its influence was manifest in school age children (Johnson et al. 1997; Merriman & Bowman, 1989). In the present study, 5-year-olds performed so poorly on asymmetry inferences that they did not show any sensitivity to the mutual exclusivity bias. In fact, 70% of their answers were incorrectly positive. Only beginning to take into account the asymmetry of inclusive relations, children of 7 years may have been more vulnerable to this bias than children of another age. Indeed, negative answers constituted 50% of all the answers they gave to each of the two problems requiring to infer to a subordinate category and only 16% of their answers to the other problem. The pattern of the 9-year-olds did not follow the same rule and seemed to be influenced by the removal of the mutual exclusivity constraint: our results showed that, at this age, it made no difference whether the inference from a superordinate had to be done to a basic or to a subordinate level category. Of all the answers given to these questions, the percentage of negative answers varied from 0 to 16%. Nine-year-olds, however, did not treat all downward inferences equally. They had more problem inferring from a basic level than from a superordinate level category, as if the hierarchical level of the category in the premise (animal or dog) took more importance in their reasoning than the category to which they had to infer. We suspect that the number of alternatives could be responsible for this pattern: the more a premise provides alternative instances for the unknown word (like in the animal premise compared to the dog premise), the more it helps the child grasping the indeterminate nature of this inference. The number of alternatives was recognized as an important factor in adult's (Cummins, 1995; Cummins, Lubart, Alksnis & Rist, 1991) as well as in children's (Janveau-Brennan & Markovits, 1999) conditional reasoning with causal inferences (If cause P, then effect Q). In this kind of inference, the number of alternative causes already known by the reasoners helps them to reason deductively and, in cases of indeterminate inference problems, to produce uncertainty responses. In the present experiment, the problems where a dax was said to be an animal (animal-dog and animal-Dalmatian) offered more possible alternatives to the interpretation of the unknown word than the dog-Dalmatian problem, where a pug was said to be a dog, simply because there are more animals than dogs. Moreover, the fact that recognition and production performance accounted for a part of variance in asymmetry understanding, only in the basic-to-subordinate inference problem, speaks for this interpretation.

Asymmetry was also assessed through the use of quantitative class-inclusion problems. These problems varied in function of the hierarchical levels of the categories involved but, contrary to Cordier's (1983) findings, no difference was found between them: the problem with a basic-level inclusive set was not easier than the problem with a superordinate inclusive set, and children demonstrated the same performance in both, whatever their age. Thus, quantitative class-inclusion problems were less influenced by hierarchical levels than qualitative inference problems although both assessed asymmetry. The absence of a hierarchical level effect in the quantitative task cannot be explained by the fact that it was too difficult or too easy for our age groups. If one adopts a Piagetian scoring, none of our children gave non-sense answers (stage 0), 48.6% claimed that the major subclass items were more numerous (stage 1 intuitive answer), 17.1% were at the transitional stage 2, and 34.3 % stated that the inclusive set was larger and correctly justified it (operational stage 3).

In contrast, qualitative inferences assessing asymmetry were influenced by the hierarchical levels of categories. This did not seem to be due to their indeterminate nature since performance on most of those inferences was not related to either recognition or production capacities, known as prerequisite capacities in indeterminacy understanding. Another difference between the tasks that can account for their differential sensitivity to the hierarchical level is their demand in terms of logical competencies. The qualitative inferences on asymmetry require the child to reason about the necessity of her conclusions while, for many researchers (Barouillet, 1989, 1992; Bideaud & Lautrey, 1983; Campbell & Jantzen, 1994; Cormier & Dagenais, 1983; Voelin, 1976), the standard quantification question does not. To correctly answer <u>If a dax is an animal, is a dax is a</u>

Dalmatian?, the child had to judge if a dax could be a Dalmatian (yes) and if a dax was necessarily a Dalmatian (no). Can this necessity aspect explain the differential sensitivity of the tasks to hierarchical levels? We do not think so. The test question of the quantification task might not call for a judgment on necessity, but Markman's (1978) "modification question"[5], added to the standard procedure, was specifically elaborated for this purpose. This modification question was not a part of our main objectives and was not analyzed as such, but was nevertheless asked to children. A post-hoc analysis of their answers showed that they either correctly answered the modification question in both the dog and the animal problems or failed both, suggesting that the vulnerability of qualitative inference to the effect of hierarchical levels, compared to the quantitative inferences, was not due to the fact that qualitative inferences evaluated necessity. Rather, we suspect that the nature of the tasks may have some influence. The quantification task is more oriented towards operations and thus less subject to the influence of representational factors like hierarchical levels.

Although few quantification problems have been presented to our subjects, the fact that hierarchical levels of category had no effect on their performance reactivates our questioning of Cordier's findings. Was the difference she observed in the performance on quantification attributable to the different hierarchical levels of the inclusive sets or to the child's different knowledge of the subsets? In the present study, as we took some precautions to make sure that children knew all the categories involved, varying the hierarchical levels did not have any effect on their quantitative reasoning about inclusion.

For qualitative inferences, however, our findings demonstrated that performance on asymmetry problems were highly sensitive to the hierarchical levels of the categories.

The developmental patterns observed in these inferences fit well and refine the last level of Blewitt's (1989) theoretical description of the development of hierarchical knowledge. Empirical evidence had demonstrated that at the first level, children acquire the ability to form categories at different levels of generality and to include the same object into multiple categories (Blewitt, 1994); then the ability to appreciate the transitive nature of inclusion relations appears in the second level and children finally understand the asymmetry of inclusion only in the third step (Deneault & Ricard, 2002; Greene, 1989, 1994). This study specifically demonstrated that the third step referring to the understanding of the asymmetry of inclusive relations is not an all-or-nothing acquisition. At 7 years, the superordinate-to-basic relation led to more understanding of asymmetry than all other two-level relations involving subordinate categories. Maybe children first begin to grasp asymmetry under conditions that are not in contradiction with the requirements of the mutual exclusivity constraint. Our 9-year-old subjects appreciated the asymmetry of inclusion also in the superordinate-to-subordinate relation and thus have made considerable progress over their younger peers. At this age, children do not seem to be under the influence of the mutual exclusivity constraint any more. However, they still experience some problems with the basic-to-subordinate relation. This difficulty may characterize the second substep where the general cognitive ability to consider alternative models is not fully developed yet. Although the existence of such substeps in the grasp of asymmetry remains to be confirmed within other domains than dogs or animals, these findings open a promising avenue for the description of asymmetry understanding, an essential acquisition leading to the mastery of inclusion.

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Table 1.

Mean Scores at Transitivity Questions as a Function of Age and Hierarchical Levels.

| | Hierarchical levels | | |
|---|---|---|---|
| Age | basic-superordinate | subordinate-basic | subordinate-superordinate |
| 5-year-olds | .64 (.50) | .55 (.69) | .73 (.47) |
| 7-year-olds | 1.58 (.67) | 1.33 (.89) | 1.33 (.89) |
| 9-year-olds | 1.67 (.65) | 1.58 (.67) | 1.67 (.49) |

Table 2.

Mean Scores at Asymmetry Questions as a Function of Age and Hierarchical Levels.

| | Hierarchical levels | | |
|---|---|---|---|
| Age | superordinate-basic | basic-subordinate | superordinate-subordinate |
| 5-year-olds | .00 (.00) | .00 (.00) | .00 (.00) |
| 7-year-olds | 1.17 (.94) | .33 (.65) | .58 (.90) |
| 9-year-olds | 1 .42 (.90) | .58 (.79) | 1.17 (1.03) |

# Footnotes

[1] Logical categorization and ecological categorization are two ways of defining human categorization. They are represented by two major psychological theories (the classical view and the prototype view), which propose distinct avenues concerning the definition of concepts, their formation, their representation, and their use. See Waxman (1991) and Rosch (1983) for more details.

[2] Some of these unfamiliar words were borrowed from Smith (1979), others from Bruderlein (1993), and some were of our own invention.

[3] French translations of the questions are available on request to the first author.

[4] Effects involving repeated measures are reported as significant only if they pass the Greenhouse and Geisser's correction criterion.

[5] Modification question : Could you make it so that there will be more rabbits than animals on the table? How?/Why not?

# Chapitre 5

## <u>Conclusion</u>

Résumé et cohérence des résultats des deux études empiriques

Nos deux études empiriques comportaient des objectifs différents. La première, présentée au chapitre 2, visait à rendre compte à la fois de la compréhension qu'a l'enfant de la transitivité et de l'asymétrie des relations inclusives et des compétences dont il dispose pour faire des inférences qualitatives ou quantitatives sur la base de ses connaissances de l'inclusion. Dans un premier temps, les résultats ont permis de conclure à une saisie plus précoce de la transitivité que de l'asymétrie. Chez les enfants de 5 et 7 ans, non seulement les inférences qualitatives impliquant la transitivité sont mieux réussies que les inférences quantitatives impliquant l'asymétrie (voir Appendice B, tableaux 1, 2 et 3), mais la transitivité est aussi mieux comprise que l'asymétrie lorsque les deux sont évaluées par des inférences qualitatives (voir Appendice B, tableaux 4, 5 et 6). Dans un deuxième temps, la tâche d'inférences qualitatives et la tâche d'inférences quantitatives se sont révélées équivalentes en offrant un compte rendu développemental très semblable de la compréhension de l'asymétrie : dans les deux tâches, les enfants de 5 ans connaissent peu de succès (95% des enfants échouent à la quantification et 83% aux inférences qualitatives) et ceux de 7 ans connaissent, encore à cet âge, des difficultés (66% d'échec contre 63 %); c'est seulement à 9 ans qu'on observe des réussites chez la majorité des sujets (seulement 29% des enfants échouent à la quantification et 37% aux inférences qualitatives). À tous les âges, aucune des deux tâches évaluant l'asymétrie n'est plus facile que l'autre (d'après les résultats obtenus pour chaque groupe d'âge, voir Tableaux 7, 8 et 9 de l'Appendice B). De plus, la performance aux deux tâches n'est pas non plus corrélée (voir les seuils de signification des coefficients Phi présentés au bas de ces tableaux) sauf pour les 5 ans, qui connaissent un taux d'échec très élevé dans les deux tâches. Donc, les capacités inférentielles de l'enfant en matière d'asymétrie, qu'elles soient de nature qualitative ou quantitative, ne sont pas décalées dans le temps mais ne semblent pas non plus dépendre d'une même habileté cognitive et pourraient relever de deux façons de traiter les informations relatives aux hiérarchies inclusives. Cette possibilité sera traitée plus loin.

La deuxième étude avait pour objectif de vérifier si l'enfant comprend mieux la transitivité et l'asymétrie des relations inclusives avec des catégories de certains niveaux hiérarchiques plutôt que d'autres, afin d'explorer plus avant les difficultés qu'il éprouve lors de la saisie de ces notions. Le niveau des catégories prises en compte n'a pas influencé la compréhension qu'ont eue les enfants de la transitivité des relations inclusives. Il est possible que cette absence d'effet soit due à l'âge des sujets. En effet, pour l'ensemble de l'échantillon, le taux de réussite aux inférences transitives a été très élevé : 80% des questions ont été réussies. Par contre, le niveau hiérarchique des catégories a eu un effet sur l'appréciation qu'ont montrée les enfants de la nature asymétrique des relations inclusives. À 7 ans, les enfants comprennent davantage l'asymétrie pour la relation entre une catégorie surordonnée et une catégorie de base que pour n'importe quel autre type de relations. À 9 ans, par contre, l'asymétrie est mieux comprise pour les relations surordonné/de base et surordonné/subordonné; l'asymétrie de la relation entre catégorie de base et catégorie subordonnée demeure la plus difficile à maîtriser. Le fait que les niveaux hiérarchiques privilégiés à un âge ne soient pas les mêmes que ceux privilégiés à un autre âge suggère que les enfants font face à des difficultés différentes à 7 et à 9 ans. Il semble que les enfants de 7 ans comprennent l'asymétrie et, par extension l'inclusion, tant que ces dernières n'entrent pas en contradiction avec un autre principe essentiel à la constitution des catégories, soit l'exclusivité mutuelle. Ce principe sert à délimiter les différentes catégories d'un même niveau (qui sont donc mutuellement exclusives l'une par rapport à l'autre) et régit les relations horizontales d'une hiérarchie. Intimement lié au développement et à l'appropriation du langage, ce principe permet au jeune enfant de comprendre que même si deux choses se ressemblent, le fait que l'une soit appelée « chat » par l'adulte et l'autre « chien » implique que l'on traite de deux choses différentes, de deux types d'objets, de deux catégories. Ainsi, dans notre tâche d'inférences qualitatives, les enfants de 7 ans ont montré des réticences à inférer qu'un dax est un dalmatien probablement parce que les dalmatiens sont déjà appelés dalmatiens et qu'il n'y a pas de sortes de dalmatiens (plusieurs enfants l'ont d'ailleurs explicitement dit). Ces enfants ont néanmoins accepté d'inférer qu'un dax est un chien, possiblement parce que cette catégorie de niveau de base comprend des sous-catégories et que le dax pouvait en être une nouvelle (l'inférence ne menaçant pas, dans ce cas, le principe d'exclusivité mutuelle).

Le développement de la pleine compréhension des hiérarchies inclusives exige de l'enfant qu'il coordonne le principe d'exclusivité mutuelle, qui implique l'existence de référents différents pour différents mots ou dénominations, et le principe de l'inclusion (ou principe hiérarchique) où un même objet peut avoir deux dénominations et « être » deux choses (un chien et un animal) en vertu des différents niveaux hiérarchiques. On ne sait pas au juste quand cette coordination entre les deux principes s'établit. D'un côté, Blewitt (1994) a montré que, dès 2-3 ans, l'enfant est capable, par la dénomination, d'inclure un même objet dans deux catégories différentes et l'on assume facilement qu'à cet âge, l'enfant distingue le chien du chat. D'un autre côté, les résultats obtenus dans notre étude montrent qu'à 7 ans, les enfants sont encore grandement influencés par le principe d'exclusivité mutuelle. Le problème auquel font face ces enfants ne tient certainement pas à l'impossibilité d'accepter deux vocables pour une même chose, de façon générale. Selon nous, c'est devant la difficulté que pose la compréhension de l'inclusion logique que l'enfant recourrait à l'exclusivité mutuelle, à défaut d'autres choix. La coordination entre le principe d'exclusivité mutuelle et le principe d'inclusion, tous deux constitutifs des systèmes hiérarchiques, pourrait donc être à refaire lorsque l'enfant est placé devant de nouvelles exigences quant à sa compréhension d'un tel système. À 9 ans par contre, malgré la difficulté que présente encore l'asymétrie, les enfants ne recourraient plus majoritairement à une stratégie primitive telle que l'exclusivité mutuelle. Dans notre situation expérimentale, ces enfants plus âgés comprennent aussi bien l'asymétrie et donc acceptent autant le caractère indéterminé de l'inférence lorsque l'inférence doit se faire vers une catégorie du niveau de base (les chiens) que lorsqu'elle doit se faire vers une catégorie du niveau subordonné comme les dalmatiens. La capacité à inférer à une catégorie de niveau subordonné qu'ont démontrée les enfants de 9 ans implique l'acceptation que le « dax » peut être un dalmatien et c'est cette acceptation même qui va à l'encontre du principe d'exclusivité mutuelle. Malgré les progrès observés chez ces enfants, leur compréhension de l'asymétrie est encore fragile et ils éprouveraient des difficultés qui seraient davantage liées à leur capacité à produire des modèles possibles pour rendre compte du nouveau mot présenté (par exemple, dax) selon le mode d'introduction de ce mot. En effet, lorsque le mot nouveau est introduit au niveau surordonné (animal), l'enfant comprend mieux l'asymétrie et l'indétermination que lorsque ce mot nouveau est introduit au niveau de base; le plus grand nombre d'exemplaires auquel peut recourir l'enfant au niveau surordonné facilite probablement la prise en compte de multiples possibilités, prise en compte qui éclaire le caractère indéterminé et donc asymétrique de la relation.

La performance des enfants aux problèmes de quantification, qui pourtant évaluent aussi la compréhension du caractère asymétrique de la relation inclusive, n'a pas été sensible à une variation du niveau hiérarchique des catégories présentées. Ce résultat peut être dû, en partie, à la nature de la tâche, davantage orientée vers des compétences opératives, et donc possiblement moins influencée par des facteurs représentationels tels les niveaux hiérarchiques. Le petit nombre de problèmes de quantification présentés dans le cadre de cette étude invite cependant à la prudence quant à cette conclusion.

Bien qu'obtenus auprès d'échantillons différents, les résultats de nos deux études sont non seulement comparables mais semblables, suggérant une certaine fiabilité de la tâche d'inférences qualitatives employée. D'abord, on retrouve une facilité relative de la transitivité par rapport à l'asymétrie dans les deux études. Dans la première étude empirique, près de 46% des enfants réussissent la transitivité tout en échouant l'asymétrie (1,4% ont le profil inverse). La deuxième étude présente des taux similaires avec 44% des enfants qui réussissent la transitivité tout en échouant l'asymétrie (aucun enfant n'a obtenu un profil inversé).

De plus, la comparaison entre la tâche d'inférences qualitatives et la tâche d'inférences quantitatives comme outil d'évaluation de la compréhension de l'asymétrie permet de tirer les mêmes conclusions dans les deux études. Selon les résultats de la première étude empirique, ces deux tâches permettent d'évaluer un même moment de développement. En effet, chez 69% de l'échantillon, on retrouve des enfants qui soit réussissaient soit rataient les deux tâches. De plus, chez les enfants qui ne réussissent qu'une des deux tâches (30,5% de l'échantillon total), 45,5% ne réussissent que la quantification et 54,5% ne réussissent que la tâche qualitative. Les deux tâches offriraient donc une description de compétences qui, bien que possiblement différentes à certains égards (puisque, par exemple, l'une s'est révélée être sensible à l'effet du niveau hiérarchique des catégories et l'autre pas), seraient contemporaines dans le parcours cognitif de l'enfant. La deuxième étude ne visait pas à comparer le niveau de difficulté relative de ces deux tâches. Néanmoins, pour la relation entre niveau surordonné et niveau de base impliquant des catégories de même niveau hiérarchique que dans la première étude, les résultats indiquent que les deux tâches d'inférence sont de difficulté comparable : la majorité des enfants réussissent ou ratent les deux tâches, mais là encore un nombre comparable d'enfants ne réussit qu'une ou l'autre des deux tâches.

Interprétation théorique de l'ensemble des résultats

Cette recherche constitue la première vérification empirique des niveaux 2 et 3 du modèle de Blewitt concernant le développement des connaissances et des habiletés relatives aux hiérarchies. Les résultats rapportés dans notre première étude empirique infirment certains aspects du modèle et en confirment d'autres, tandis que ceux de notre deuxième étude raffinent notre compréhension des difficultés auxquelles est confronté l'enfant aux prises avec les exigences de la tâche d'inférences qualitatives. Ils fournissent, de plus, des indices quant à certaines des compétences requises dans la saisie de la notion d'asymétrie lorsqu'elle est évalué par cette tâche. Les résultats rapportés permettent aussi de nuancer certains aspects du modèle de Campbell et Bickhard (1986).

*Le modèle de Blewitt.* D'abord, les résultats infirment l'hypothèse de Blewitt selon laquelle la distinction entre les niveaux 2 et 3 de son modèle tient au type d'inférences que l'enfant peut effectuer. Dans le modèle proposé, l'habileté à produire des inférences qualitatives caractériserait le deuxième niveau alors que l'habileté à produire des inférences quantitatives déterminerait le troisième niveau. Bien que soulevée par d'autres auteurs (Markman, 1989), l'hypothèse d'un délai développemental entre l'habileté à produire des inférences qualitatives et celle à produire des inférences quantitatives est infirmée par les résultats de notre première étude. Ainsi, lorsque les deux types de raisonnement inférentiel –qualitatif ou quantitatif- portent sur une même notion, par exemple l'asymétrie, ils sont maîtrisés au même âge. Les différents niveaux décrivant le développement de la compréhension des systèmes hiérarchiques tiendraient davantage à la notion sous-tendant l'inférence qu'au type même d'inférence. Ainsi, au niveau 2, l'enfant serait en mesure de compléter des inférences qui exigent la compréhension de la transitivité des relations inclusives. La compréhension du caractère asymétrique de ces relations formerait l'essentiel du troisième niveau.

D'ailleurs, à partir de 7 ans, on n'observe plus chez nos sujets d'amélioration significative de leur performance aux inférences qualitatives évaluant la transitivité. Ces résultats s'harmonisent parfaitement avec la tendance actuelle qui considère la capacité de raisonnement transitif comme une acquisition du début de l'âge scolaire. Un relevé récent de la documentation portant sur la capacité de l'enfant à raisonner de façon transitive (en dehors du contexte de l'inclusion des classes) permet de conclure que empiriques l'âge d'acquisition de cette compétence varierait entre 4 et 8 ans selon les tâches utilisées et la présence d'indices facilitateurs (Wright, 2001).

Notre deuxième étude empirique jette un premier éclairage quant aux difficultés que présentent, pour l'enfant, les inférences qualitatives évaluant l'asymétrie. En effet, ni Greene (1989, 1991, 1994), ni Johnson et al. (1997), qui ont aussi utilisé des inférences qualitatives, ne se sont penchés sur ce point. Outre la difficulté liée à l'indétermination, difficulté que nous avons abordée dans notre chapitre théorique et sur laquelle nous reviendrons, la présente étude fait ressortir l'existence du principe d'exclusivité mutuelle qui semble, même à l'âge scolaire, guider les stratégies de l'enfant. Habituellement présent chez l'enfant d'âge préscolaire, ce biais cognitif s'est avéré actif chez les enfants de 7 ans qui ont davantage compris l'asymétrie lorsqu'elle ne s'opposait pas au principe d'exclusivité. Nos résultats suggèrent également qu'avec le temps, le principe d'exclusivité mutuelle perdrait de son influence sur la performance aux inférences évaluant l'asymétrie, au profit du nombre de modèles (*alternative models*) pouvant constituer des possibilités dans une situation indéterminée, c'est-à-dire, dans notre condition expérimentale, du nombre d'animaux pouvant être représentés par le mot nouveau de la prémisse. Les enfants de 9 ans ont semblé sensibles à ce facteur.

*L'approche des niveaux de connaissance de Campbell et Bickhard.* Malgré la difficulté que comporte la maîtrise de la notion d'asymétrie des relations inclusives, cette acquisition ne complète pas la description développementale de l'ensemble des acquisitions relatives aux hiérarchies inclusives. Le modèle de Campbell et Bickhard (1986), dont s'est inspirée Blewitt (1989), offre, entre autres, une description pouvant rendre compte du développement ultérieur à la saisie de l'asymétrie. Cependant, nos résultats remettent en cause certains aspects de ce modèle.

Inspiré du modèle interactif d'acquisition des connaissances (« Interactive model of knowing ») de Bickhard (1978), Campbell et ses collègues (Campbell, 1992; Campbell & Bickhard, 1986; Campbell & Bickhard, 1992, Campbell & Jantzen, 1994) ont proposé une théorie du développement qui tente de rendre compte des changements survenant dans différents domaines du développement cognitif, allant par exemple de la compréhension qu'a l'enfant de l'esprit humain –domaine communément appelé théorie de l'esprit- à sa compréhension des systèmes hiérarchiques basés sur l'inclusion. Cette approche dite des niveaux de connaissance (« knowing-levels approach ») est donc beaucoup plus étoffée que le modèle de Blewitt de par le spectre des phénomènes développementaux qu'elle décrit et par le fait qu'elle s'intéresse non seulement aux étapes qui marquent le développement mais aux mécanismes (l'apprentissage et l'abstraction réfléchissante) qui expliquent le passage d'une étape à une autre. Bien qu'elle rejette la conception structurale de la théorie piagétienne (entre autres dans sa description des compétences de l'enfant en termes mathématiques et logiques et dans son concept de structure d'ensemble propre à chaque stade), cette approche, qui a vu le jour aux États-Unis, adopte pourtant plusieurs concepts piagétiens (l'interactionnisme nécessaire au développement, l'importance de l'abstraction réfléchissante et de la prise de conscience dans le développement cognitif, la place accordée au développement de la nécessité dans le raisonnement déductif, l'intérêt pour l'épistémologie génétique et pour la naissance de la nouveauté dans le développement).[1]

Comme plusieurs autres modèles élaborés dans les mêmes années (Moshman & Timmons, 1982; Karmiloff-Smith, 1979), l'approche des niveaux de connaissance

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[1] L'approche des niveaux de connaissance s'oppose aussi aux approches du traitement de l'information et aux théories néopiagétiennes entre autres pour leur conception de la nature des représentations (voir

propose une description du développement qui s'appuie sur une utilisation itérative de la connaissance où chaque niveau de connaissance (appelé aussi système de connaissance) est lui-même « connu » ou compris à un autre niveau, reliant ainsi un premier niveau de connaissance implicite à des niveaux de connaissance explicite. Le modèle proposé peut donc comporter un nombre variable de niveaux selon le domaine considéré. Pour ce qui est de la saisie de la notion d'inclusion, les auteurs ont proposé trois niveaux de connaissance auxquels correspondent des habiletés distinctes (on reconnaît facilement ici l'influence que ce modèle a pu avoir sur Blewitt). Le premier niveau consisterait en une compréhension implicite des relations catégorielles hiérarchiques et rendrait compte de la capacité des enfants à utiliser des catégories liées hiérarchiquement sans pouvoir raisonner sur elles ou sur les liens qu'elles entretiennent (Campbell, 1992). Au deuxième niveau, la connaissance de ces relations et de leurs propriétés devient explicite pour l'enfant qui peut ainsi produire certaines inférences logiques. Ce niveau caractériserait l'enfant qui comprend la transitivité et l'asymétrie des relations inclusives et qui réussit, vers 8 ans, la quantification de l'inclusion. Enfin, le troisième niveau porte sur une connaissance explicite des propriétés des connaissances du niveau 2. L'enfant du niveau 3 comprend la nécessité logique de la relation d'inclusion et ce, quelles que soient les modifications proposées aux classes impliquées dans le problème de quantification de l'inclusion. Les compétences de ce niveau sont manifestes chez les enfants qui réussissent les questions « modification » et « écran » de Voelin (1976) et de Markman (1978). Ces questions s'ajoutent à la procédure standard du problème de quantification et sont posées aux enfants qui réussissent la question de quantification en déclarant qu'il y a plus de fruits que d'oranges sur la table et qui justifient leur réponse. Elles portent sur la

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Campbell et Bickhard, 1986, p. 35 pour plus de détails).

possibilité ou l'impossibilité de rendre une sous-classe plus grande que la classe englobante (Modification : *Peux-tu faire quelque chose pour qu'il y ait plus d'oranges que de fruits sur la table?* Écran : un écran est placé de façon à ce que l'enfant ne voit plus le matériel : *Maintenant, j'enlève quelques fruits. Peux-tu me dire, sans regarder, s'il y a plus d'oranges ou plus de fruits sur la table?*). Ces questions sont sensées mesurer la compréhension qu'a l'enfant de la nécessité de la relation inclusive et sont réussies vers 11 ans.

La réussite tardive à ces dernières questions ont amené Markman (1978), Voelin (1976) et aussi Bideaud (1980, 1988) à considérer que la réussite à la tâche de quantification serait de nature empirique plutôt que logique. Certains travaux (Dagenais, 1973; Cormier et Dagenais, 1983) ont toutefois remis en question cette conception selon laquelle une compréhension empirique précéderait une compréhension logique. En effet, les enfants qui réussissent la quantification ne recourraient pas nécessairement à des stratégies de décompte et beaucoup fournissent des arguments logiques pour justifier leurs réponses. De plus, la performance à la question de modification ne varie pas chez les enfants selon qu'ils utilisent le décompte ou l'argument logique comme justification dans la tâche de quantification. Si la réussite à la quantification exige aussi une compréhension logique de l'inclusion, comment expliquer alors le décalage entre cette réussite et la réussite aux questions de Markman? L'approche des niveaux de connaissances proposée par Campbell pour rendre compte du développement de la compréhension de l'inclusion constitue, selon nous, la seule tentative d'explication offrant une réponse cohérente à cette question. Par sa distinction entre un niveau implicite et un niveau explicite d'appropriation de la relation inclusive, cette approche propose une des avenues les plus intéressantes pour rendre compte du décalage entre la réussite à la quantification et la réussite aux questions de Markman.

Cependant, les résultats que nous avons obtenus appellent des nuances quant à la constitution ou au nombre de niveaux formant le modèle de Campbell. Par exemple, le deuxième niveau proposé par les auteurs, celui des connaissances explicites débutant à 4 ans et se terminant vers 8-9 ans (Campbell & Bickhard, 1986; Campbell 1992), devait rendre compte 1) de l'habileté de l'enfant à réussir des inférences qualitatives concernant la transitivité et l'asymétrie des relations inclusives et 2) de son habileté à réussir à la tâche de quantification de l'inclusion. Nos résultats portent plutôt à croire que, d'une part, la compréhension de l'asymétrie (lorsqu'elle est évaluée par des inférences qualitatives) requiert une certaine appropriation de la nécessité qui serait de même niveau que celle requise par l'épreuve de quantification et que, d'autre part, la compréhension de la transitivité n'exigerait pas une appropriation de la nécessité, c'est-à-dire qu'elle n'exigerait pas un niveau d'abstraction aussi élevé. Si tel est le cas, la compréhension de la transitivité et la capacité de faire des inférences transitives ne pourraient légitimement faire partie du niveau 2 du modèle de Campbell. Par contre, elles ne sauraient non plus être le propre du niveau 1 tel que décrit par les auteurs. En effet, on devrait retrouver dans ce niveau l'enfant qui utilise des catégories liées hiérarchiquement (et donc des catégories de différents niveaux hiérarchiques) mais qui est encore incapable de produire les inférences logiques caractéristiques du niveau 2. Dès lors, l'emplacement de la saisie de la transitivité dans la séquence développmentale est difficile à identifier : soit que la transitivité constitue une acquisition du premier niveau (qu'on doit alors peut-être considérer comme un niveau logique), soit qu'elle se distingue de ces premières acquisitions et, dans ce cas, porterait le nombre de niveaux à inclure dans le modèle à quatre. La définition des quatre niveaux de la séquence que nous proposons s'inspire du modèle de développement de la nécessité logique dans le raisonnement déductif de Moshman (Moshman,1990; Moshman & Timmons, 1982)[2] mais appliquée ici au développement des connaissances relatives à la notion d'inclusion. La séquence développementale suggérée diffère aussi de celle de Moshman pour ce qui est des âges et comprendrait :

1) un premier niveau caractérisé par la compréhension implicite des relations catégorielles et des inférences qu'elles pourraient permettre. C'est l'utilisation des catégories qui prime, en ce sens que ce qui est explicite pour le sujet ce sont les catégories évoquées (par exemple, le sujet peut parler de tel ou tel chien qu'il connaît sans répondre à la question). Ce niveau correspondrait au niveau 1 de Campbell. On peut supposer qu'il coïncide avec le premier niveau de Blewitt. Les enfants qui affichent ce type de conduite auraient entre 2 et 4 ans.
2) un deuxième niveau, que nous appellerons logique-inférentiel, est défini par une une appropriation explicite de l'inférence et de son utilisation. Cette connaissance explicite de l'inférence pourrait être soutenue par une saisie implicite de l'inclusion logique et de ses propriétés. À ce niveau, l'enfant, âgé de 4 à 7 ans d'après nos résultats, est capable de produire des inférences et donc de répondre aux questions d'inférence posées sur la relation inclusive mais seulement quant à la transitivité car l'asymétrie requiert une compréhension à tout le moins implicite

[2] Ce modèle (Moshman & Timmons, 1982) du parcours développemental menant à une saisie de la nécessité logique, où l'on retrouve des niveaux de connaissance explicite qui succèdent à des niveaux implicites, témoigne de l'influence mutuelle que Moshman et Campbell ont eue l'un sur l'autre. Leur

de la nécessité qu'il n'a pas encore. Le caractère logique de ce niveau reste à déterminer. Dans son relevé de la documentation sur la capacité des enfants à raisonner transitivement, Wright (2001) laisse entendre que certains raisonnements transitifs démontrés par les enfants les plus jeunes (4-5 ans) pourraient ne pas être de même nature que ceux des enfants de 7-8 ans et seraient davantage de type associatif que logique surtout lorsque la procédure expérimentale repose sur un sur-apprentissage (« overlearning ») dû à une présentation répétée des prémisses. Les expériences rapportées dans cette recension de la documentation ne s'inscrivent pas dans le contexte de l'inclusion des classes mais portent sur des relations comme « plus grand que » (A>B, B>C, A?C). Bien que la procédure habituellement utilisée pour l'étude de la compréhension du caractère transitif des relations inclusives ne favorise pas la constitution de liens associatifs en cours d'expérimentation (aucun apprentissage, cotation des justifications), les connaissances préalables de l'enfant quant aux hiérarchies pourraient avoir le même genre d'influence.

3) un troisième niveau, où l'enfant saisit le caractère asymétrique de la relation, est fondé sur une connaissance explicite de l'inclusion et une connaissance implicite de la nécessité. On observe alors une réussite aux inférences qualitatives concernant l'asymétrie et à la quantification de l'inclusion. Nos travaux ont montré que ce type de performance caractérise presque la moitié des enfants de 7 ans et la majorité des enfants de 9 ans. Le fait que, à ce niveau, plusieurs enfants justifient leurs réponses aux questions indéterminées en ayant recours à des

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modèle se ressemble au point que nous avons jugé préférable de ne pas les rapporter tous les deux afin d'éviter d'alourdir inutilement le texte.

arguments logiques pourrait signifier toutefois que leur connaissance de la nécessité est plus explicite que prévu. Certains travaux récents (Morris, 2000) tendent à démontrer une appropriation progressive et explicite de la nécessité logique chez les enfants de 8 à 13 ans. Si tel était le cas, le niveau 3 pourrait être le dernier niveau du modèle. Sinon, la description des conduites du niveau 3 pourrait couvrir une portion du développement qui s'étendrait jusqu'à 10 ans, âge où débuterait alors le quatrième niveau.

4) un quatrième et dernier niveau, déjà identifié par Campbell et dont l'utilité dépend de la constitution du niveau 3, où l'enfant démontre une connaissance explicite de la nécessité. Cette connaissance explicite se manifesterait, par exemple, par la réussite aux questions « modification » et « écran » vers 10-11 ans.

Quel que soit le nombre de niveaux ou quelles que soient les modifications qui peuvent lui être apportées, le modèle de Campbell et Bickhard fournit une description qui permet de rendre compte de l'ensemble des compétences de l'enfant et de leur évolution. De plus, et contrairement au modèle de Blewitt, il tient compte de la notion de nécessité logique, notion incontournable dans le développement de la compréhension de l'inclusion et du raisonnement déductif.

*Compréhension intensionelle et extensionnelle*. Nos résultats montrent que la tâche d'inférences qualitatives et la tâche d'inférences quantitatives (quantification de l'inclusion), ayant toutes deux pour fonction d'évaluer la compréhension de l'asymétrie des relations inclusives, semblent présenter un même niveau de difficulté puisque aucune n'est mieux réussie et ce, que ce soit pour l'ensemble des sujets ou pour chacun des groupes d'âge pris isolément. Les deux tâches pourraient évaluer exactement le même concept. Or, certains enfants ne réussissent que la tâche d'inférences qualitatives tandis que d'autres ne réussissent que la tâche de quantification, ce qui suggère que, même si elles portent sur un même concept, ces deux tâches évaluent des compétences ou des habiletés différentes. Constitutrices de différences individuelles probablement transitoires dans le parcours développemental, ces deux types de compétences caractériseraient deux groupes distincts d'enfants mais se développeraient à un même âge chez ces deux groupes.

Cette interprétation serait conforme à ce que Barouillet (1992) a découvert à un niveau un peu plus avancé de la compréhension de l'inclusion. Cherchant à mettre en parallèle le développement de la notion d'inclusion et celui de la notion de complément, Barouillet a observé pour chaque niveau de la notion d'inclusion (niveau de réussite à la quantification et niveau de réussite à la question « modification » de Markman) des niveaux correspondants pour la notion de complément (réussite à la tâche de « complémentation du complément »[3] et réussite à la tâche d'« inclusion dans le complément »[4]). Fait intéressant, Barouillet a détecté l'existence d'une phase

[3] Le sujet dispose de 20 animaux de bois (5 vaches, 5 lapins, 5 chiens, 5 moutons) et est placé devant un dessin comportant 12 cases faisant office de cages. On lui raconte un récit dans lequel un autre enfant, en passant devant ces cages un peu plus tôt, a vu qu'elles n'étaient pas vides, qu'il y avait un animal dans chaque cage et que huit de ces animaux n'étaient pas des lapins. Puis on demande au aujet de « mettre les animaux dans les cages comme le petit garçon les a vus ». Cette tâche exige du sujet qu'il recompose la classe englobante (les 12 animaux dans les cages) seulement à partir de renseignements sur une classe complémentaire (les non-lapins) et le contraint à composer le complément (les 4 lapins) puis à inférer ce qui peut compléter ce dernier.

[4] L'enfant dispose de 32 animaux de bois (8 moutons, 8 vaches, 8 chiens, 8 lapins). On lui raconte un récit semblable à celui de la tâche de complémentation du complément (CC), mais cette fois les informations sont : 12 cages; un animal dans chaque cage, aucune cage vide; il y 7 non-lapins et 4 moutons. Une construction avec disjonction de ces deux dernières classes (où l'on trouverait 7 non-lapins qui ne sont pas non plus des moutons, 4 moutons et 1 lapin) témoignerait du caractère non logique du complément construit à la tâche de complémentation du complément.

intermédiaire entre les premier et deuxième niveaux. Cette phase intermédiaire se distinguerait par une réussite partielle aux questions du deuxième niveau : certains sujets réussissent les questions de modification mais ratent les questions d'inclusion dans le complément tandis que d'autres montrent le profil inverse. Ces patterns de réponse différentiels résulteraient de deux approches, deux traitements différents des informations hiérarchiques. Certains sujets, ceux qui réussissent la question de modification, utiliseraient un traitement propositionnel : ils réfléchissent davantage aux propriétés des objets, aux ressemblances et aux différences, et se centrent sur les rapports d'appartenance objet/classe, c'est-à-dire sur l'intension de la classe. On peut dire qu'ils font preuve de logique intensionnelle. Les autres, ceux qui réussissent l'inclusion dans le complément, utiliseraient un traitement imagé, analogique, plus global : ils réfléchissent davantage à la complémentarité des classes, à la réunion et à la partition qui en découlent et se centrent donc davantage sur les emboîtements des classes. Ils comprennent les classes dans leur extension et démontrent une logique extensionnelle.

Cette distinction entre logique intensionnelle et logique extensionelle pourrait constituer une piste explicative quant aux deux types de compétences en matière d'asymétrie. En effet, il nous semble que la tâche d'inférences qualitatives, portant justement sur les rapports d'appartenance objets/classes, soit plus propice à une analyse intensionnelle des rapports hiérarchiques que la tâche de quantification de l'inclusion. Ainsi, il est possible que les enfants qui réussissent exclusivement la tâche d'inférences qualitatives, pour ce qui est de l'appropriation de l'asymétrie, fassent preuve d'une logique intensionelle portant sur la définition des classes. La tâche de quantification de l'inclusion s'intéresse davantage à l'ensemble des membres d'une classe qu'à sa définition et, en ce sens, nous semble plus près de la logique extensionnelle. Longtemps négligée par Piaget, l'identification d'une logique intensionnelle constitue le thème principal d'un de ses écrits posthumes (Piaget et Garcia, 1987). Bien que cette forme de logique y soit conçue comme une logique précoce relativement à la logique extensionnelle, les résultats obtenus par Barrouillet donnent plutôt à penser que la logique intensionelle continuerait d'évoluer.

Défis et perspectives de recherche

Le travail accompli dans cette thèse nous convie inévitablement à considérer celui qui reste à faire. Parmi les perspectives de recherche qu'il suscite, certaines tiennent davantage du défi tandis que d'autres, toutes aussi intéressantes, sont plus aisément réalisables. Parmi celles-ci, nous retenons l'investigation des niveaux plus précoces de compréhension des relations hiérarchiques. En débouchant sur des précisions et des ajustements à apporter quant à la constitution des niveaux 2 et 3 du modèle de Blewitt, les constats empiriques de cette thèse appellent peut-être une redéfinition du niveau 1 et des frontières qui le séparent du niveau 2. Plus particulièrement, une vérification du statut développemental des habiletés observées par Blewitt (1994) chez l'enfant de niveau 1 (capable de former des catégories de différents niveaux hiérarchiques et d'inclure un même objet dans plusieurs de ces catégories) par rapport aux habiletés à produire des inférences qualitatives respectant la transitivité des relations inclusives entre ces catégories permettrait de compléter le modèle.

Nous retenons également le besoin de généraliser nos résultats à d'autres domaines de connaissances que celui des animaux. La similitude de nos résultats par rapport à ceux de Greene (1989, 1991, 1994), qui a utilisé un matériel fictif, laisse cependant présumer que la difficulté relative de l'asymétrie par rapport à la transitivité devrait s'étendre à d'autres domaines.

Enfin, comme nos deux études ont été menées simultanément, ce qui a empêché qu'elles se nourrissent l'une l'autre, nous retenons la possibilité de vérifier l'influence que pourraient avoir les contraintes que nous avons identifiées dans notre deuxième étude empirique (particulièrement celle de l'exclusivité mutuelle) dans la détermination des modèles construits par l'enfant pour se représenter les relations intercatégorielles, modèles décrits dans notre première étude. Cet objectif serait facilement accessible en présentant plusieurs problèmes (au moins trois) et ce, pour la relation entretenue entre chaque combinaison de catégories de niveaux hiérarchiques différents. Cette procédure pourrait de plus nous renseigner sur la nature de ces représentations mentales, à savoir si ces dernières sont influencées par des informations exogènes, comme le niveau hiérarchique des catégories, ou si elles participent davantage des différences individuelles.

La définition des différents niveaux de compréhension des relations hiérarchiques, l'identification de leur séquence d'apparition et leur généralisation à plusieurs domaines de connaissances ne sauraient suffire pour élaborer un modèle du développement de l'inclusion. La question de la nécessité de l'inclusion et les problèmes de mesure qu'elle occasionne dans les situations indéterminées devront être abordés. Dans la présente thèse, la considération des justifications de l'enfant dans de telles situations a non seulement permis d'investiguer la manière dont il aborde ces situations mais a aussi, grâce à l'analyse des patterns de réponses, ouvert la voie à l'identification de la représentation mentale qu'il a des relations hiérarchiques en situations indéterminées. Néanmoins, l'élaboration de nouvelles tâches où la compréhension qu'a l'enfant de la situation indéterminée ne reposerait pas sur l'analyse de ses justifications (des tâches présentant, par exemple, plusieurs choix de réponses, chacun rendant compte d'une stratégie propre comme dans la tâche de la boîte de Piéraut-Le Bonniec (1980), mais adaptées à l'évaluation de la compréhension des relations inclusives) compléterait avantageusement la tâche d'inférences qualitatives et constituerait certainement une avancée méthodologique majeure. En effet, malgré les années de recherche consacrées à la notion de nécessité logique et l'effervescence qu'elle a soulevée (voir par exemple les travaux de Piaget, 1981, 1983; Moshman & Timmons, 1982; Moshman, 1990; Morris, 2000; Overton, 1990; Smith, 1993; 1997 sans parler des travaux issus de la philosophie et de la logique), on ne s'entend pas encore sur une définition de cette notion, ni sur une explication de son origine chez l'enfant, ni surtout sur les moyens nécessaires et les critères à adopter pour en évaluer l'acquisition. C'est cette entreprise qui nous semble aussi près du défi que de la perspective de recherche, si tant est que les deux ne logent pas toujours à la même enseigne. *« ...La réalité recule à mesure que le sujet s'en approche, et cela parce que soulevant de nouveaux problèmes au fur et à mesure qu'elle est mieux connue* » (Piaget dans son dernier écrit, publié en 1987 en collaboration avec Garcia, p. 146).

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## Appendice A

## Description des tâches expérimentales

# I. EXPÉRIENCE 1

## A. Tâche d'inférences qualitatives

Tâche contrôle
(pour les enfants qui passent la condition avec matériel seulement).

Des images d'animaux sont disposées sur la table devant l'enfant. L'expérimentateur (E) demande *« Est-ce que ce sont tous des animaux? »*

Si l'enfant répond par l'affirmative, l'E. passe à la tâche expérimentale. Sinon, il enlève l'image (ou les images) que l'enfant considère n'être pas une image d'animal. E doit répéter la question et enlever les images jusqu'à ce que, pour l'enfant, il ne reste que des images d'animaux.

Tâche expérimentale

La tâche d'inférence qualitative est une entrevue semi-clinique. Certaines questions (questions test) ont été posées à tous les enfants. Ce sont les réponses à ces questions qui ont été soumises aux analyses statistiques.

D'autres questions ont parfois été posées afin de bien comprendre le point de vue de l'enfant et, lorsque la situation l'exigeait, certaines précautions ont été prises (comme, par exemple, faire répéter la prémisse après l'avoir donnée).

Lorsqu'un mot non familier (comme « tabby ») était connu de l'enfant, l'expérimentatrice prenait alors un autre mot non familier.

La présentation des mots non familiers, appelés « mots nouveaux » pour l'enfant pouvait varier selon le mot présenté afin de s'assurer que l'enfant ne confonde pas ce mot avec un mot connu de même consonnance. Par exemple, dans le cas du mot nouveau « tabby », l'expérimentatrice pouvait dire, « … c'est pas un tapis, c'est pas un crayon, c'est pas un chandail non plus, …c'est un animal ».

Trois types de problèmes sont soumis à l'enfant : des problèmes de transitivité (T1, T2, T3), des problèmes d'asymétrie (A1, A2, A3) et des problèmes contrôles (C1 et C2). Chaque problème d'asymétrie est invariablement suivi d'une question de production (P), d'une question de reconnaissance (R1) et d'une autre question de reconnaissance servant de contrôle (R2).

Dans ce document, la présentation des premières questions de chaque type (le premier problème de transitivité (T1) et le premier problème d'asymétrie ainsi que les questions de production et de reconnaissance qui lui sont relatives (A1, P, R1, R2) contient des consignes ou des questions complémentaires pouvant être posées à l'enfant. Ces questions complémentaires ne seront pas répétées ici pour les autres problèmes de transitivité (T2, T3) et d'asymétrie (A2, A3).

**Consigne de départ**

*« Je vais maintenant te poser des questions. Dans mes questions, je vais avoir un mot nouveau, un mot que tu n'as jamais entendu, mais tu vas quand même être capable de répondre à la question; tu vas voir, c'est facile. »*

**Questions test / transitivité**

**T1**. *Sais-tu c'est quoi un dax?*_____ *C'est normal, c'est un mot nouveau. Un dax c'est un chien.* (Faire répéter la prémisse : *C'est quoi un dax?*_____ *c'est bien.*) *Si un dax est un chien, est-ce qu'un dax est un animal?* _______ *Pourquoi c'est ...*(un… ou c'est pas un…)*?*____________________________________________

____________________________________________

**T2**. *Sais-tu c'est quoi un sof? Un sof est un mouton. Si un sof est un mouton, est-ce qu'un sof est un animal?* ____ *Pourquoi c'est...?* ______________________

____________________________________________

**T3**. *Sais-tu c'est quoi un dem? Un dem est un cheval. Si un dem est un cheval, est-ce qu'un dem est un animal?* _____ *Pourquoi c'est ...?* ______________________

____________________________________________

**Questions test / asymétrie**

**A1**. *Sais-tu c'est quoi maintenant un loris? Un loris est un animal. Si un loris est un animal, est-ce qu'un loris est un tigre?* ________ *Pourquoi c'est ...?* ______________________

____________________________________________

(Si réponse affirmative :*Est-ce que t'es sûr(e) qu'un loris c'est un tigre?*____________)

P. *Est-ce que ça peut être autre(s) chose(s) qu'un tigre , un loris?*[1] ________ *Qu'est-ce que ça peut être?*____________________________________________

____________________________________________

[1] Lorsque l'enfant n'a pas accepté l'inférence qui précède en A1, la question de production est formulée différemment : Alors, qu'est-ce que ça pourrait être un loris?

R1. *Est-ce que ça peut être un écureuil, un loris?* ______ *Pourquoi ça peut ….?* ______
______________________________________________________________________________

*(Est-ce que t'es sûr(e) qu'un loris c'est un écureuil?*________________________*)*

R2. *Est-ce que ça peut être un épis de maïs, un loris?* ____ *Pourquoi ça peut…?* _____
______________________________________________________________________________

Si l'enfant a produit plusieurs exemplaires à la question P : *Tu m'as dit qu'un loris ça pouvait être un tigre, un ours…, …,…. Est-ce que ce sont tous des loris ça ou est-ce que que c'est un de ceux-là qui est un loris?* ______________________________________
______________________________________________________________________________

**A2**. *Sais-tu c'est quoi un tabby? Un tabby est un animal. Si un tabby est un animal, est-ce qu'un tabby est un chameau?* ______ *Pourquoi c'est…?* ______________________
______________________________________________________________________________

(Si réponse affirmative :*Est-ce que t'es sûr(e) qu'un tabby c'est un chameau?*_________)

P. *Est-ce que ça peut être autre(s) chose(s) qu'un chameau un tabby?*_____ *Qu'est-ce que ça peut être?*______________________________________________________
______________________________________________________________________________

R1. *Est-ce que ça peut être un kangourou, un tabby?* _____ *Pourquoi ça peut…?* ____
______________________________________________________________________________

R2. *Est-ce que ça peut être un raisin, un tabby?* _____ *Pourquoi ça peut…?* _________
______________________________________________________________________________

**A3**. *Sais-tu c'est quoi un fox? Un fox est un animal. Si un fox est un animal, est-ce qu'un fox est un zèbre?* ______ *Pourquoi c'est…?* ______________________________
______________________________________________________________________________

(Si réponse affirmative : *Est-ce que t'es sûr(e) qu'un fox c'est un zèbre?*_________)

P. *Est-ce que ça peut être autre(s) chose(s) qu'un zèbre un fox ?* _____ *Qu'est-ce que ça peut être?* ______________________________________________________
______________________________________________________________________________

R1. *Est-ce que ça peut être un singe, un fox?* ____ *Pourquoi ça peut…?* ___________
______________________________________________________________________________

R2. *Est-ce que ça peut être un biscuit, un fox?* _____ *Pourquoi ça peut...?* __________
______________________________________________________________________

**Questions test /contrôle**

**C1**. *On sait qu'un dax c'est un chien. Si un dax est un chien est-ce qu'un dax est un chat?* _____ *Pourquoi c'est...(ou c'est pas...)?*____________________________________
______________________________________________________________________

**C2**. *On sait qu'un dem est un cheval. Si un dem est un cheval, est-ce qu'un dem est un ours?* ____ *Pourquoi c'est...(ou c'est pas...)?*____________________________________
______________________________________________________________________

## B. Tâche de quantification de l'inclusion
## (Inférences quantitatives)

Voici l'exemple d'un problème de quantification. Chaque enfant passe trois problèmes de quantification comptant 7 animaux. Dans cet exemple, ce sont les images de 5 lapins et 2 cochons qui sont disposées sur la table de manière aléatoire.

**Problème 1 : version a**
Questions préliminaires

*Qu'est-ce qu'on a sur la table ...(prénom de l'enfant)... :* ______________

______________

*Peux-tu me montrer tous les lapins avec ton doigt?*

*Peux-tu me montrer tous les cochons?*

*Les lapins, ils sont des animaux?* _______

*Les cochons, ils sont des animaux?* ______

Question d'inclusion

*Sur la table ...(prénom de l'enfant)..., est-ce qu'il y a plus d'animaux ou plus de lapins?*
______________________________________________

*Pourquoi tu dis qu'il y a plus de...?* ______________________________
______________________________________________

Si l'enfant réussit, l'expérimentateur pose la question de modification ci-dessous. Si non, il passe à la version b du problème (avec questions facilitantes).

Question de modification

*D'après toi, est-ce qu'on peut faire quelque chose pour que, sur la table, on ait plus de lapins que d'animaux?* ________.
Si oui : *Qu'est-ce qu'on peut faire... (pour qu'il y ait plus de lapins que d'animaux)?*___
______________________________________________

Si non : *Pourquoi on peut pas...( faire quelque chose pour qu'il y ait plus de lapins que d'animaux)?* ______________________________

______________________________

**Problème 1 : version b**

Questions préliminaires

*Sur la table, est-ce que ce sont tous des lapins?* ______

*Est-ce que ce sont tous des animaux?* ________

*Si je prenais tous les lapins qu'il y a sur la table et que je les enlevais, est-ce qu'il resterait quelque chose?* ________ *(Qu'est-ce qui resterait?)* ______________________

*Si je prenais tous les animaux qu'il y a sur la table et que je les enlevais, est-ce qu'il resterait quelque chose?* _______________ *(Qu'est-ce qui resterait?)* _______________

Question d'inclusion

*Sur la table,... (prénom de l'enfant)... est-ce qu'il y a plus de lapins ou plus d'animaux?*

______________________________

*Pourquoi tu dis qu' il y a plus de ...?* ______________________________

______________________________

Si l'enfant réussit, l'expérimentateur pose la question de modification ci-dessous. Si non, il passe à un autre problème.

Question de modification

*D'après toi, est-ce qu'on peut faire quelque chose pour que, sur la table, on ait plus de lapins que d'animaux?* ________.

Si oui : *Qu'est-ce qu'on peut faire... (pour qu'il y ait plus de lapins que d'animaux)?* ___

______________________________

Si non : *Pourquoi on peut pas...( faire quelque chose pour qu'il y ait plus de lapins que d'animaux)?* ______________________________

## II. EXPÉRIENCE 2

### A. Tâche contrôle-chiens

Des images de chiens (dalmatiens, caniches, bergers allemands, boxers, Saint-Bernard,...) et d'animaux (qui ne sont pas des chiens) sont disposées sur la table devant l'enfant.

L'expérimentateur (E) demande : *« Sur la table, il y a des animaux. Il y en a qui sont des chiens. Est-ce que tu peux me montrer des chiens? Est-ce qu'il y a des sortes de chiens que tu connais là-dedans? Peux-tu me donner le nom des sortes de chiens que tu connais? »*

E. inscrit le nom des sortes de chiens sur les lignes 1, 2 et 3 ci-dessous et reprend ces catégories dans les termes de l'enfant (par exemple, beaucoup d'enfants ont fait référence à la classe des Saint-Bernard par « des Beethovens », dû à un film populaire qui passait au moment de l'expérimentation et qui mettait en vedette un Saint-Bernard,) autant pour les questions ci-dessous que pour la tâche expérimentale.

Aavant de passer à la tâche expérimentale, l'expérimentateur pose des questions sur l'appartenance des trois des sortes de chiens retenues (en 1, 2, et 3) à la catégorie des chiens et à celle des animaux. Les même questions sont ensuite posées pour deux autres animaux qui ne sont pas des chiens afin de s'assurer que l'enfant ne réponde pas n'importe quoi. Pour toutes ces question préliminaires, l'expérimentateur encercle la réponse donnée par l'enfant.

1. ___________________

*Est-ce que c'est un chien?* O N

*Est-ce que c'est un animal?* O N

2. ___________________

Est-ce que c'est une chien? O N

Est-ce que c'est un animal? O N

3. ___________________

*Est-ce que c'est un chien?* O N

*Est-ce que c'est un animal?* O N

4. Chat

*Est-ce que c'est un chien?* O N

*Est-ce que c'est un animal?* O N

5. Lapin

*Est-ce que c'est un chien?* O N

*Est-ce que c'est un animal?* O N

Enfin, l'expérimentateur demande *« Est-ce ce sont tous des chiens sur la table? »* _____ *« Peux-tu enlever toutes les images qui ne sont pas des chiens? » « Là, est-ce qu'il y a encore des images qui ne sont pas des chiens? »*

La question est répétée, jusqu'à ce que l'enfant affirme qu'il ne reste que des chiens. L'expérimenateur rajoute alors les autres animaux (chat, lapin, cheval cochon). Cette procédure vise à enlever les sortes de chiens qui, pour l'enfant, sont inconnues et qui, même, ne font pas partie des chiens.

## B. Tâche d'inférences qualitatives

Tâche expérimentale

Trois types de problèmes sont soumis à l'enfant : des problèmes de transitivité (T1, T2, T3), des problèmes d'asymétrie (A1, A2, A3) et des problèmes contrôles (C1 et C2). Chaque problème d'asymétrie est invariablement suivi d'une question de production (P), d'une question de reconnaissance (R1) et d'une autre question de reconnaissance servant de contrôle (R2).

Dans ce document, la présentation des premières questions de chaque type (le premier problème de transitivité (T1) et le premier problème d'asymétrie ainsi que les questions de production et de reconnaissance qui lui sont relatives (A1, P, R1, R2) contient des consignes ou des questions complémentaires pouvant être posées à l'enfant. Ces questions complémentaires ne seront pas répétées ici pour les autres problèmes de transitivité (T2, T3) et d'asymétrie (A2, A3).

Les problèmes portent sur les chiens connus par l'enfant, tels qu'identifiés dans la chiens ici = dalmatien, bouledogue et golden retriever)

### Consigne de départ

*« Je vais maintenant te poser des questions. Dans mes questions, je vais avoir un mot nouveau, un mot que tu n'as jamais entendu, mais tu vas quand même être capable de répondre à la question; tu vas voir, c'est facile. »*

### Questions test /transitivité

**T1**. *Sais-tu c'est quoi un dax?*___ *C'est sûr c'est un mot nouveau. Un dax est un chien. Si un dax est un chien, est-ce qu'un dax est un animal?* _______ *Pourquoi c'est ...?* ___
______________________________________________________________________________

**T2**. *Sais-tu c'est quoi un sof? Un sof est un golden retriever. Si un sof est un golden retriever, est-ce qu'un sof est un chien?* ____ *Pourquoi c'est...?* ___________________
______________________________________________________________________________

**T3**. *On sait qu'un sof est un golden. Si un sof est un golden, est-ce qu'un sof est un animal?* _____ *Pourquoi c'est...?* _____________________________________________
______________________________________________________________________________

**Questions test / asymétrie**

**A1**. *On sait qu'un dax est un chien. Si un dax est un chien, est-ce qu'un dax est un dalmatien?* ________ *Pourquoi c'est ...?* ______________________________________

______________________________________________________________________

(Si réponse affirmative : *Est-ce que t'es sûr(e) qu'un dax c'est un dalmatien?*________ )

P. *Est-ce que ça peut être autre(s) chose(s) qu'un dalmatien, un dax?*[2] ______ *Qu'est-ce que ça peut être?* ______________________________________________

______________________________________________________________________

*R1. Est-ce que ça peut être un bouledogue, un dax?* ______ *Pourquoi ça peut...?* _____

______________________________________________________________________

(*Est-ce que t'es sûr(e) qu'un dax c'est un bouledogue?*________________________ )

R2. *Est-ce que ça peut être un cochon, un dax?* ___ *Pourquoi ça peut...?* ____________

______________________________________________________________________

Si l'enfant a produit plusieurs exemplaires à la question P : *Tu m'as dit qu'un dax ça pouvait être un dalmatien, un caniche, .... Est-ce que ce sont tous des dax ça ou est-ce que c'est un de ceix-là qui est un dax?* ____________________________________

______________________________________________________________________

**A2**. *Sais-tu c'est quoi un tabby? Un tabby est un animal. Si un tabby est un animal, est-ce qu'un tabby est un chien?* ______ *Pourquoi c'est...?* _________________________

______________________________________________________________________

(Si réponse affirmative : *Est-ce que t'es sûr(e) qu'un tabby c'est un chien?* __________ )

P. *Est-ce que ça peut être autre(s) chose(s) qu'un chien, un tabby?* ______ *Qu'est-ce que ça peut être?* ______________________________________________

______________________________________________________________________

R1. *Est-ce que ça peut être un cheval, un tabby?* _____ *Pourquoi ça peut être...?* _____

______________________________________________________________________

R2. *Est-ce que ça peut être un épi de maïs, un tabby?* ____ *Pourquoi ça peut ...?*_____

______________________________________________________________________

[2] Lorsque l'enfant n'a pas accepté l'inférence qui précède en A1, la question de production est formulée différemment : Alors, qu'est-ce que ça pourrait être un dax?

**A3**. *On sais qu'un tabby est un animal. Si un tabby est un animal, est-ce qu'un tabby est un bouledogue?* ______ *Pourquoi c'est ...?* ________________________________________
________________________________________________________________________

(Si réponse affirmative : *Est-ce que t'es sûr(e) qu'un tabby c'est un bouledogue?* _____ )

P. *Est-ce que ça peut être autre(s) chose(s) qu'un bouledogue, un tabby?* _______ *Qu'est-ce que ça peut être?* ______________________________________________
________________________________________________________________________

R1. *Est-ce que ça peut être un chat, un tabby?* _____ *Pourquoi ça peut ...?* _________
________________________________________________________________________

R2. *Est-ce que ça peut être un raisin, un tabby?* _____ *Pourquoi ça peut...?* _________
________________________________________________________________________

**Questions test / contrôle**

**C1**. *On sais qu'un dax est un chien. Si un dax est un chien, est-ce qu'un dax est un chat?* ____ *Pourquoi c'est...(ou c'est pas...)?* ________________________________________

**C2**. *On sait qu'un sof est un golden. Si un sof est un golden, est-ce qu'un sof est un dalmatien?* ____ *Pourquoi c'est ...(ou c'est pas...?* ______________________________
________________________________________________________________________

**C. Tâche de quantification de l'inclusion
(Inférences quantitatives)**

L'enfant est soumis à deux problèmes de quantification.

L'un d'eux, aussi présenté aux sujets de la première étude empirique, porte sur une classe inclusive de niveau surordonné, la classe des animaux, et sur des sous-classes de niveau de base, la classe des lapins et celle des cochons (c.f. p. 185 pour le détail de la procédure).

Dans l'autre problème de quantification, la classe inclusive est celle des chiens. Les deux sous-classes sont deux sortes de chien connues de l'enfant et sont donc de niveau subordonné, par exemple, 5 dalmatiens et 2 bouledogues.

## Appendice B

**Répartition des sujets de l'étude 1 en fonction de leur réussite et de leur échec aux différentes tâches et en fonction de l'âge**

Tableau 1 : Fréquence des réussites et des échecs des enfants de 5 ans aux tâches de transitivité et de quantification de l'inclusion.

| | Quantification | | |
|---|---|---|---|
| Transitivité | Échec | Réussite | Total |
| Échec | 9 | 0 | 9 |
| Réussite | 14 | 1 | 15 |
| Total | 23 | 1 | 24 |

McNemar : $p < 0.001$
Phi : $p = 0.43$

Tableau 2 : Fréquence des réussites et des échecs des enfants de 7 ans aux tâches de transitivité et de quantification de l'inclusion.

| | Quantification | | |
|---|---|---|---|
| Transitivité | Échec | Réussite | Total |
| Échec | 1 | 1 | 2 |
| Réussite | 15 | 7 | 22 |
| Total | 16 | 8 | 24 |

McNemar : $p = 0,001$
Phi : $p = 0.60$

Tableau 3 : Fréquence des réussites et des échecs des enfants de 9 ans aux tâches de transitivité et de quantification de l'inclusion.

| | Quantification | | |
|---|---|---|---|
| Transitivité | Échec | Réussite | Total |
| Échec | 0 | 1 | 1 |
| Réussite | 7 | 16 | 23 |
| Total | 7 | 17 | 24 |

McNemar : $p = 0.07$
Phi : $p = 0.51$

Tableau 4. Fréquence des réussites et des échecs des enfants de 5 ans aux deux tâches d'inférences qualitatives : transitivité et asymétrie.

| | Inf. qual./asymétrie | | |
|---|---|---|---|
| Inf. qual/transitivité | Échec | Réussite | Total |
| Échec | 9 | 0 | 9 |
| Réussite | 11 | 4 | 15 |
| Total | 20 | 4 | 24 |

McNemar : $p = 0{,}001$
Phi : $p = 0.09$

Tableau 5. Fréquence des réussites et des échecs des enfants de 7 ans aux deux tâches d'inférences qualitatives : transitivité et asymétrie.

| | Inf. qual./asymétrie | | |
|---|---|---|---|
| Inf. qual/transitivité | Échec | Réussite | Total |
| Échec | 2 | 0 | 2 |
| Réussite | 13 | 9 | 22 |
| Total | 15 | 9 | 24 |

McNemar : $p < 0{,}001$
Phi : $p = 0{,}25$

Tableau 6. Fréquence des réussites et des échecs des enfants de 9 ans aux deux tâches d'inférences qualitatives : transitivité et asymétrie.

| | Inf. qual./asymétrie | | |
|---|---|---|---|
| Inf. qual/transitivité | Échec | Réussite | Total |
| Échec | 0 | 1 | 1 |
| Réussite | 9 | 14 | 23 |
| Total | 9 | 15 | 24 |

McNemar : $p = 0{,}02$
Phi : $p = 0{,}43$

Tableau 7. Fréquence des réussites et des échecs des enfants de 5 ans aux deux tâches évaluant l'asymétrie : inférences qualitatives et inférences quantitatives.

| | Inf. qualitatives | | |
|---|---|---|---|
| Inf. quantitatives | Échec | Réussite | Total |
| Échec | 20 | 3 | 23 |
| Réussite | 0 | 1 | 1 |
| Total | 20 | 4 | 24 |

McNemar : p = 0,25
Phi : p = 0,02

Tableau 8. Fréquence des réussites et des échecs des enfants de 7 ans aux deux tâches évaluant l'asymétrie : inférences qualitatives et inférences quantitatives.

| | Inf. qualitatives | | |
|---|---|---|---|
| Inf. quantitatives | Échec | Réussite | Total |
| Échec | 11 | 5 | 23 |
| Réussite | 4 | 4 | 1 |
| Total | 20 | 4 | 24 |

McNemar : p = 1,00
Phi : p = 0,371

Tableau 9. Fréquence des réussites et des échecs des enfants de 9 ans aux deux tâches évaluant l'asymétrie : inférences qualitatives et inférences quantitatives.

| | Inf. qualitatives | | |
|---|---|---|---|
| Inf. quantitatives | Échec | Réussite | Total |
| Échec | 3 | 4 | 7 |
| Réussite | 6 | 11 | 17 |
| Total | 9 | 15 | 24 |

McNemar : $p = 0.75$
Phi : $p = 0.73$

## Appendice C

**Permission relative à l'inclusion des articles dans la thèse**

# Accord de la coauteure

Identification de l'étudiant

Joane Deneault
Ph. D. psychologie

Articles visés

The assessment of children's understanding of inclusion relations : Transitivity, asymmetry, and quantification (2002). Soumis à Developmental Psychology.

The effect of hierarchical levels of categories on children's deductive inferences about inclusion (2002). Soumis à International Journal of Psychology.

Déclaration

À titre de coauteure des deux articles identifiés ci-dessus, je suis d'accord pour que Joane Deneault inclut ces articles dans sa thèse de doctorat qui a pour titre « Le développement de la hiérarchisation logique des catégories ».

[redacted] 30/10/2002

Marcelle Ricard date